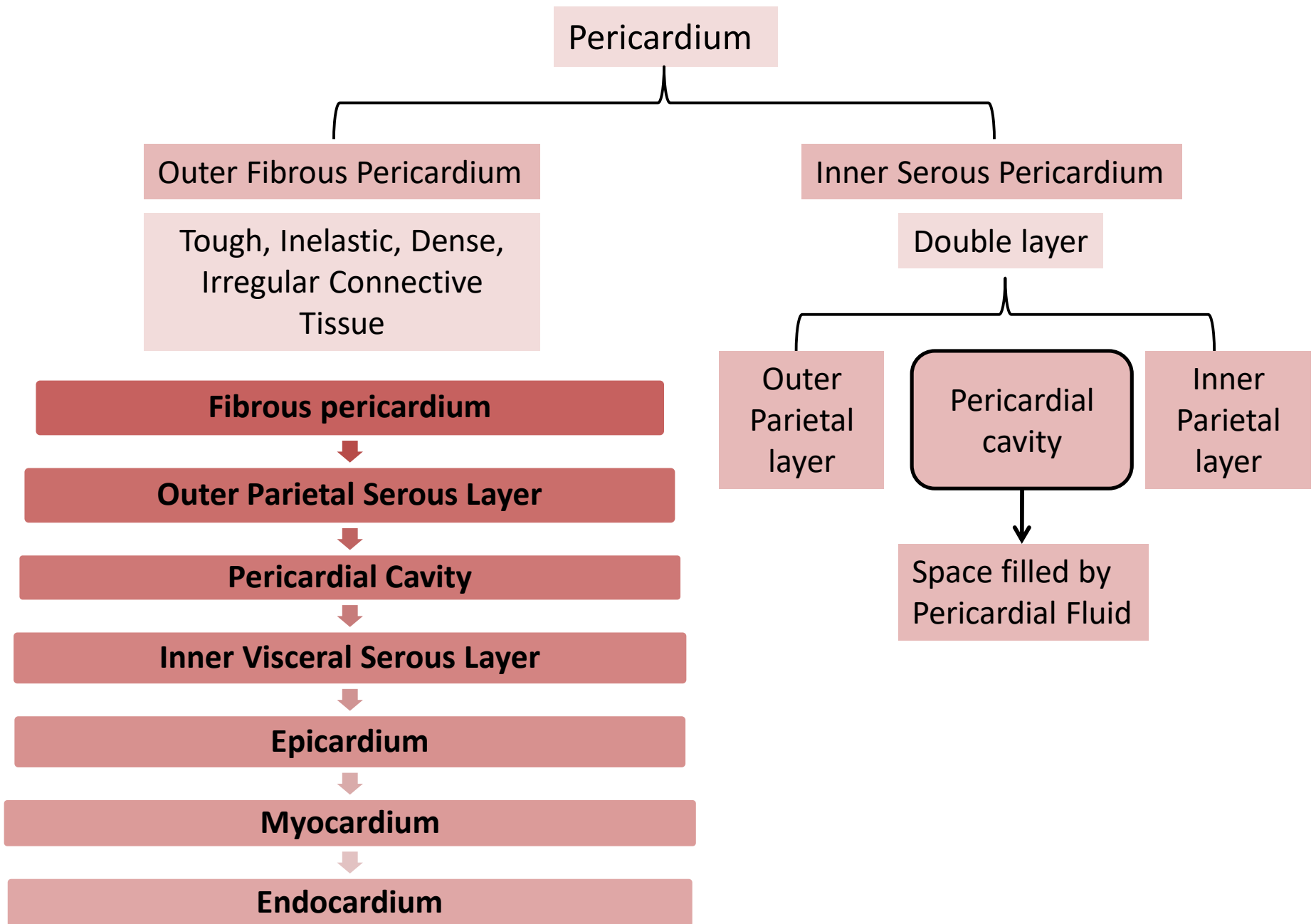


Cardiovascular system

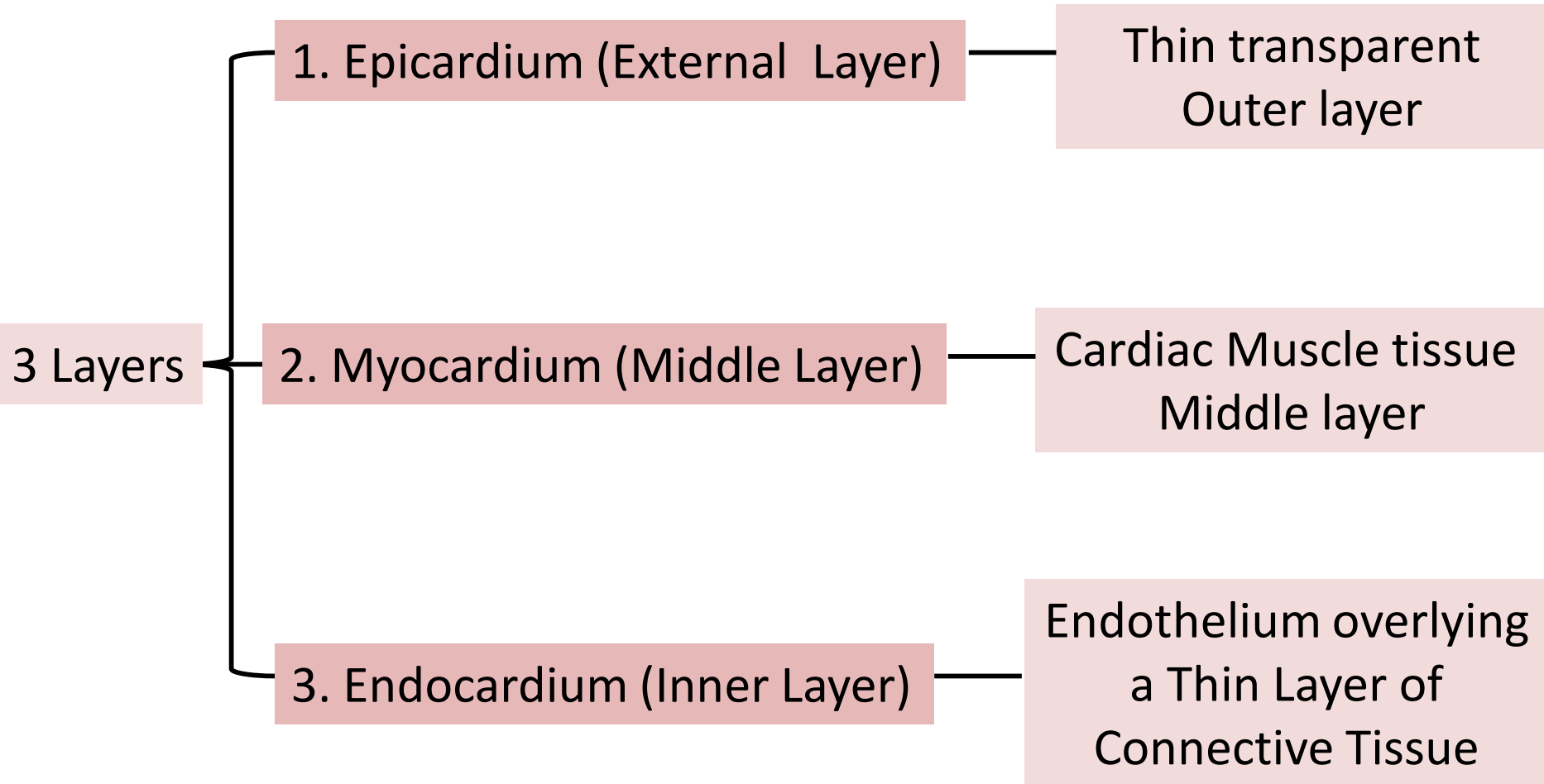
Heart

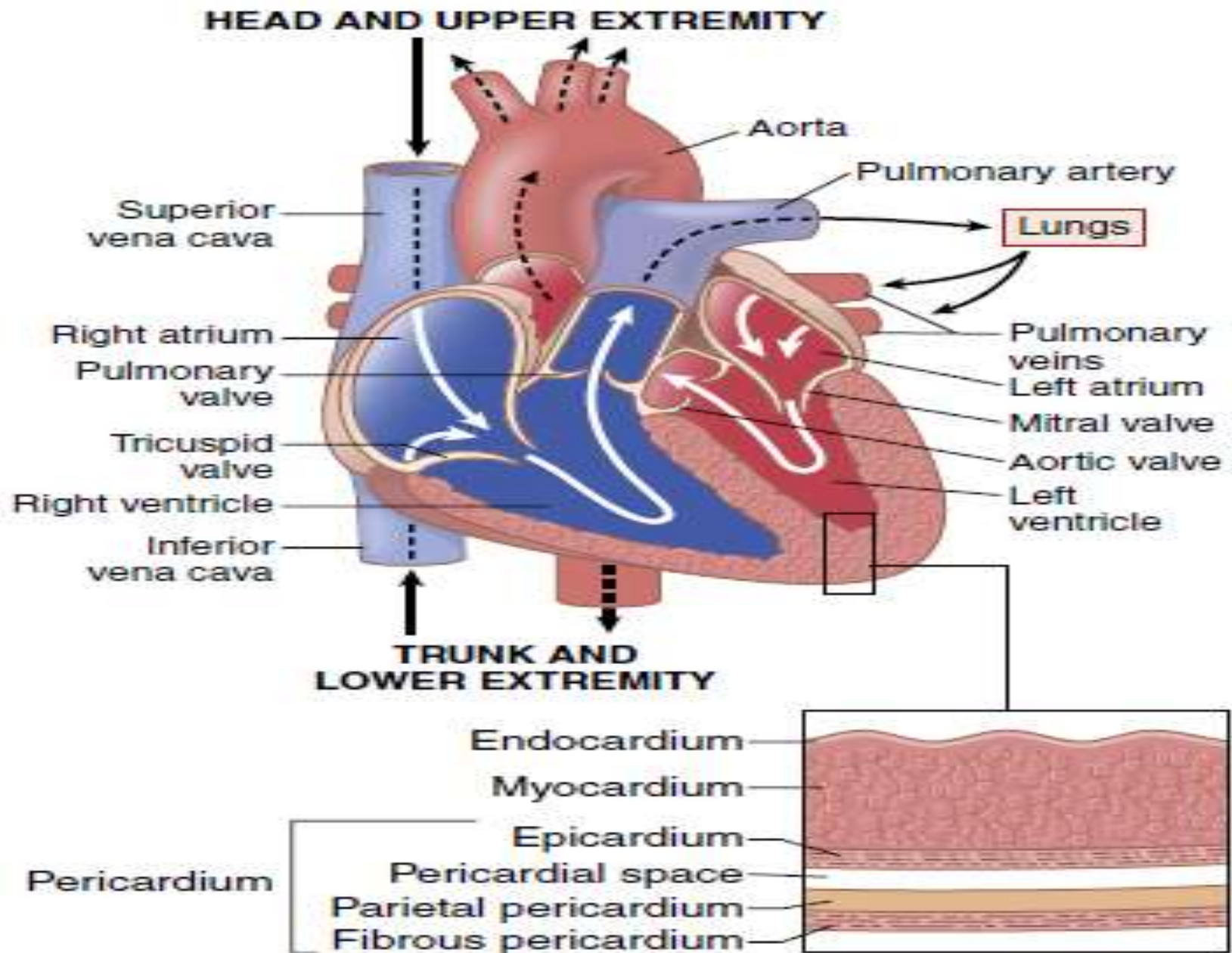
- Mesodermally derived organ
- **Location:** Thoracic (Chest) cavity, in between two lungs, slightly tilted to left lung.
- Pericardium: membrane surrounds and protects Heart





Layers of Heart wall





Source: John E Hall, Michael E Hall (2021), Guyton and Hall Textbook of Medical Physiology (14th Edition), Page no.114

Chambers of Heart

4 Chambers

```
graph TD; A[4 Chambers] --> B[2 Superior chambers]; A --> C[2 Inferior chambers]; B --> D[Right ATRIA]; B --> E[Left ATRIA]; C --> F[Right VENTRICLE]; C --> G[Left VENTRICLE];
```

2 Superior chambers

Right
ATRIA

Left
ATRIA

2 Inferior chambers

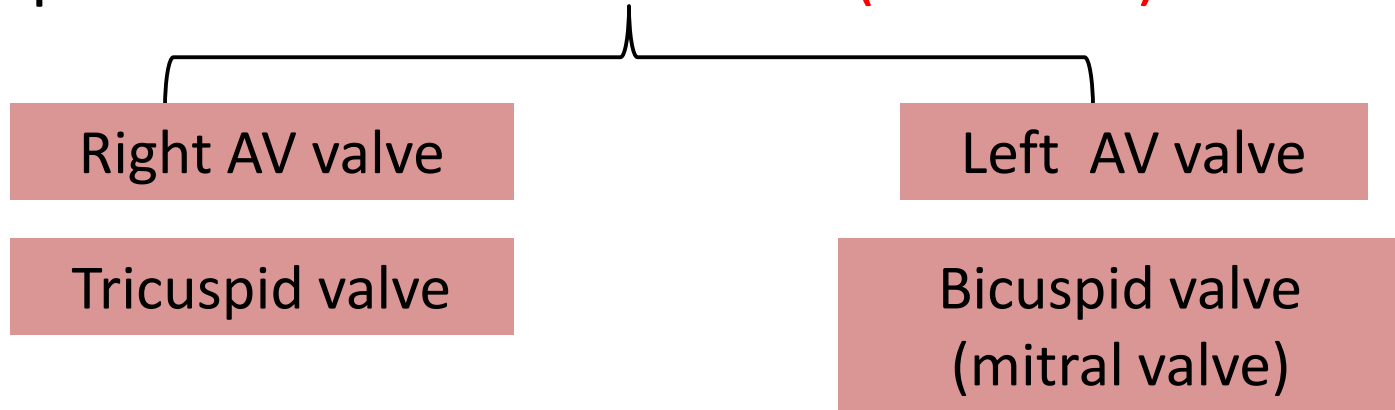
Right
VENTRICLE

Left
VENTRICLE

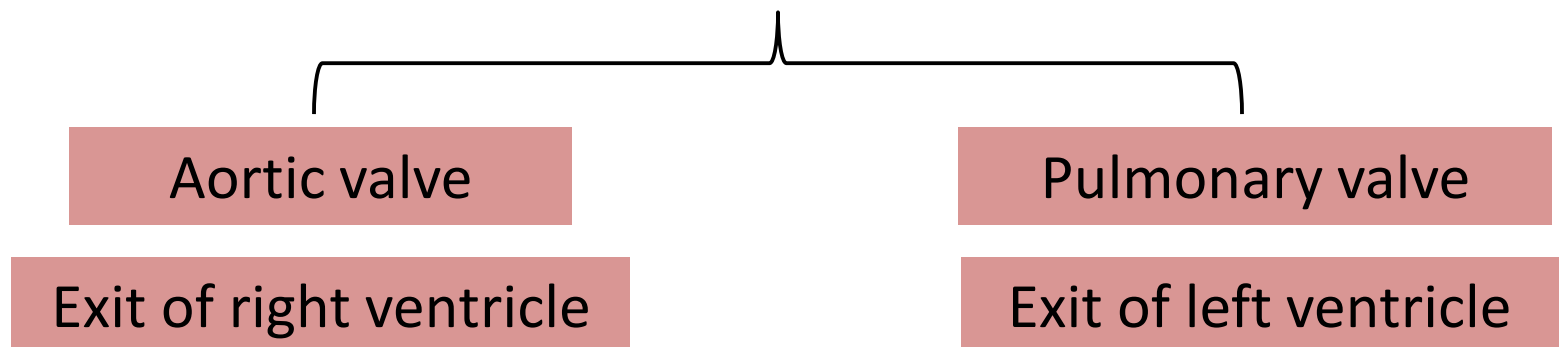
Valves of Heart

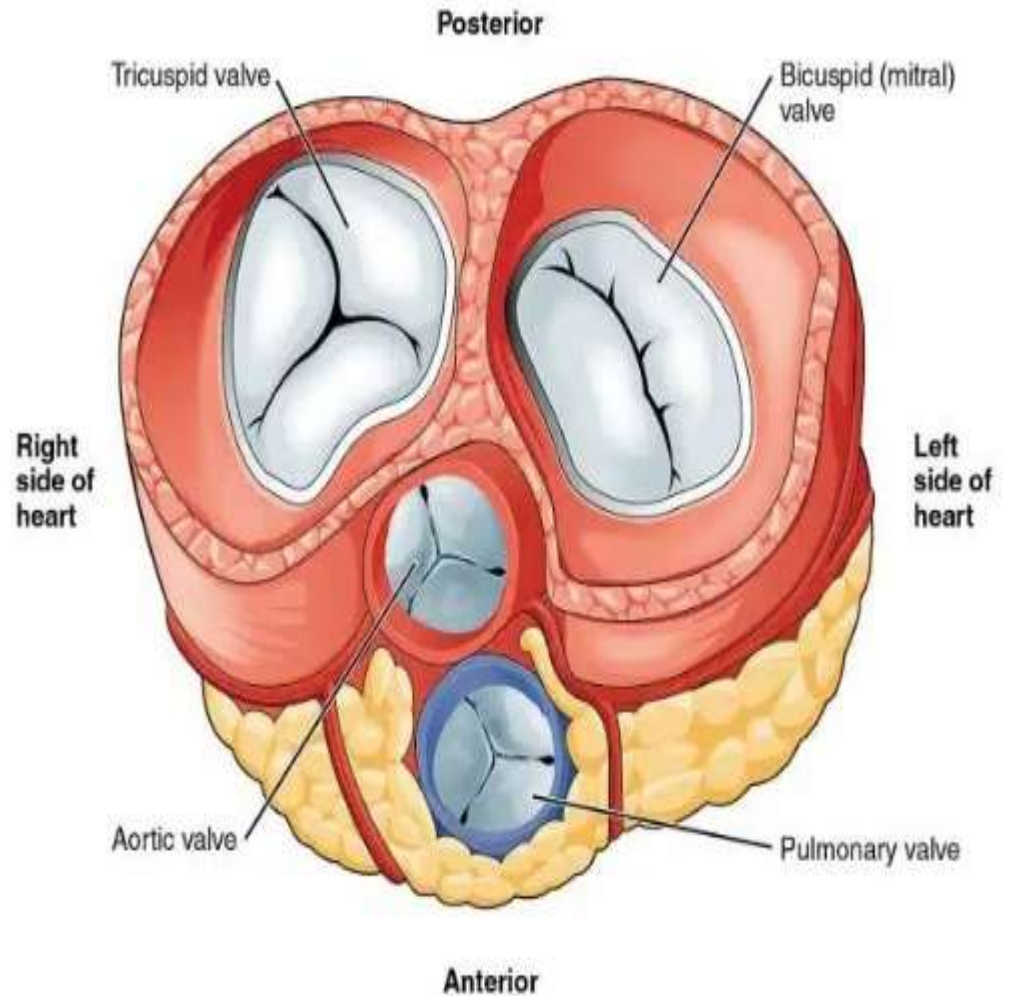
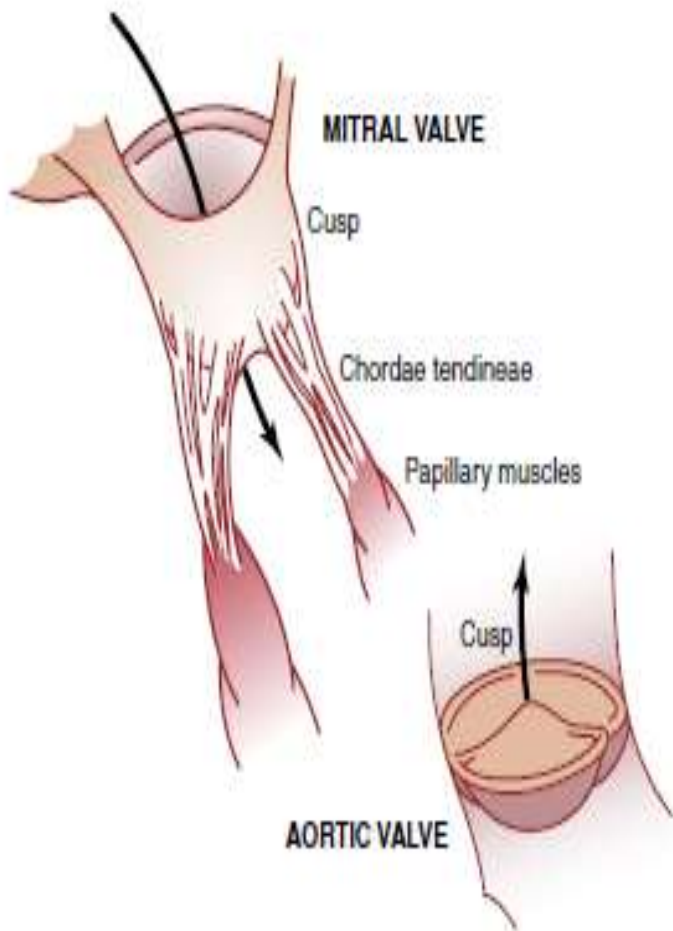
- 2 pairs of valves:

- 1st pair- **Atrioventricular valve (AV Valve)**



- 2nd Pair- **Semi lunar valve (mood shaped cusps)**





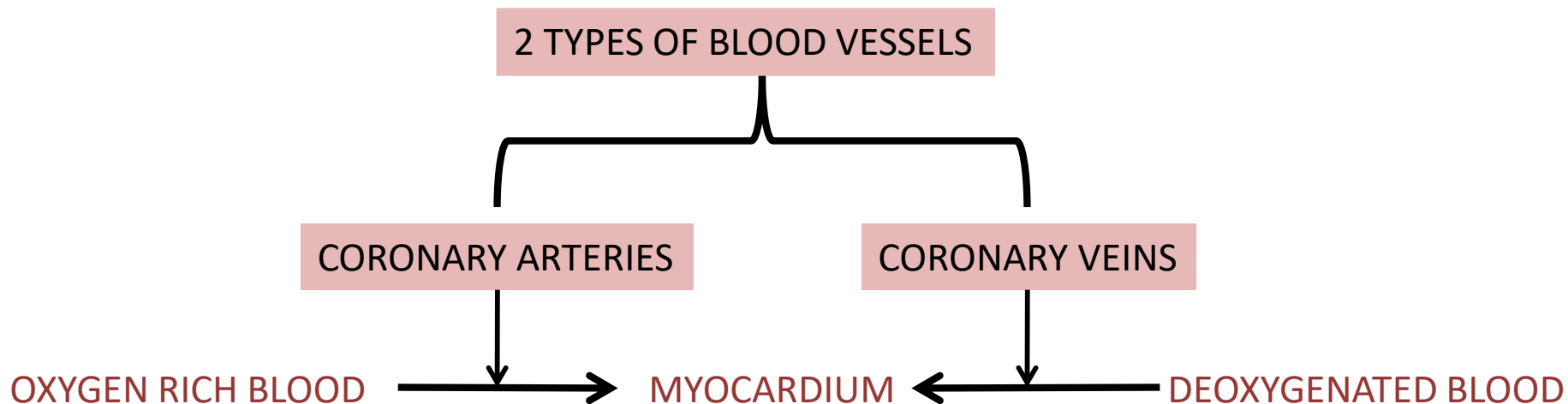
Source:

Source: John E Hall, Michael E Hall (2021),
Guyton and Hall Textbook of Medical
Physiology (14th Edition), Page no.120

<https://teachmeanatomy.info/thorax/organs/heart/heart-valves/>

Coronary /Cardiac circulation

- Circulation of blood in Blood Vessels Of Heart Muscle (Myocardium)



- **Arteries**- Small Diameter, May block- Heart Attack
- **Myocardial Infraction**- Portion of Heart Muscle dies due to lack of Oxygen
- **Angina Pectoris**- Coronary Artery- Partial Block, Pain in Left Arm.

Cardiac conduction system

Heart – Cardiac muscle

- (network of specialized cardiac muscle fibers) –
auto rhythmic fibers (self excitable)

- **AUTO RHYTHMIC FIBERS**

 - » Generate Action Potential

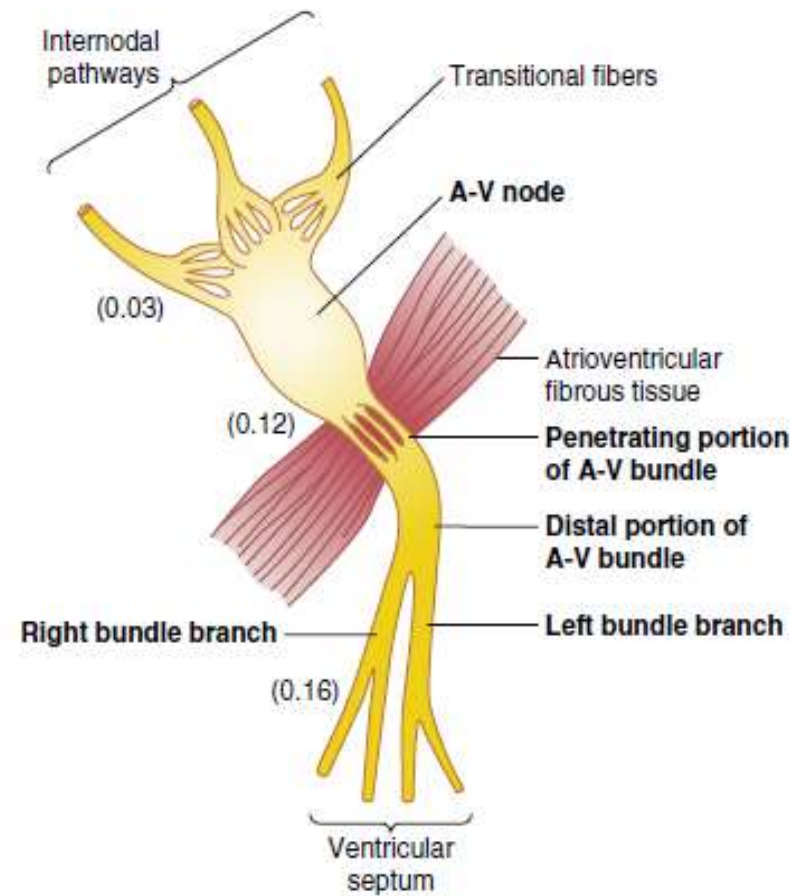
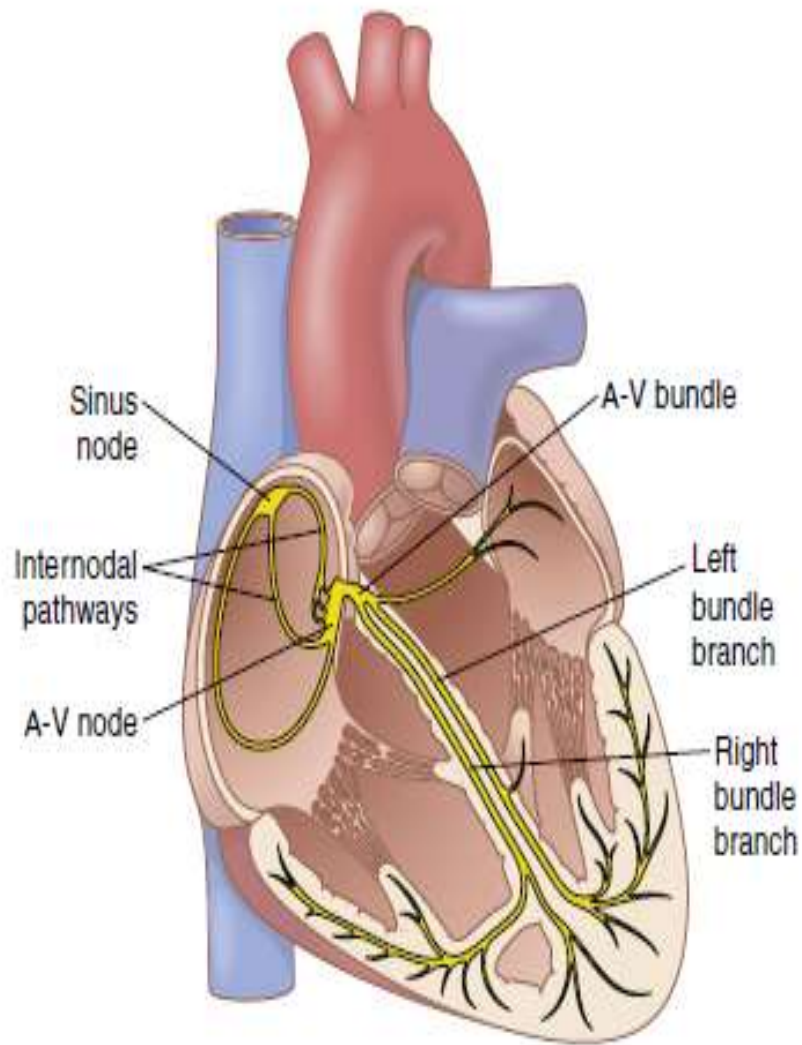
 - » Trigger Heart Contractions

 - » Stimulate Heart- To Beat After It Is Removed
From The Body

- **IMPORTANCE: ENSURING THAT CHAMBERS OF
HEART CONTRACT IN A COORDINATED MANNER**

Components of cardiac conduction system

1. Sino atrial node(SA node)
2. Atrioventricular node (AV node)
 3. Bundle of His
 4. Purkinje Fibers



Source: John E Hall, Michael E Hall (2021), Guyton and Hall Textbook of Medical Physiology (14th Edition), Page no.128,129

SINOATRIAL NODE (Heart's Pacemaker) – Located in right atrial wall

Cardiac action potential= 70-75/min

Causes contraction of heart

Propagates throughout both Atria via Gap Junctions

Atria contracts

By conducting along atrial muscle fibers

Action potential passes to AV Node- located in interatrial septum

Action potential passes to Bundle of His (Atrioventricular Bundle)

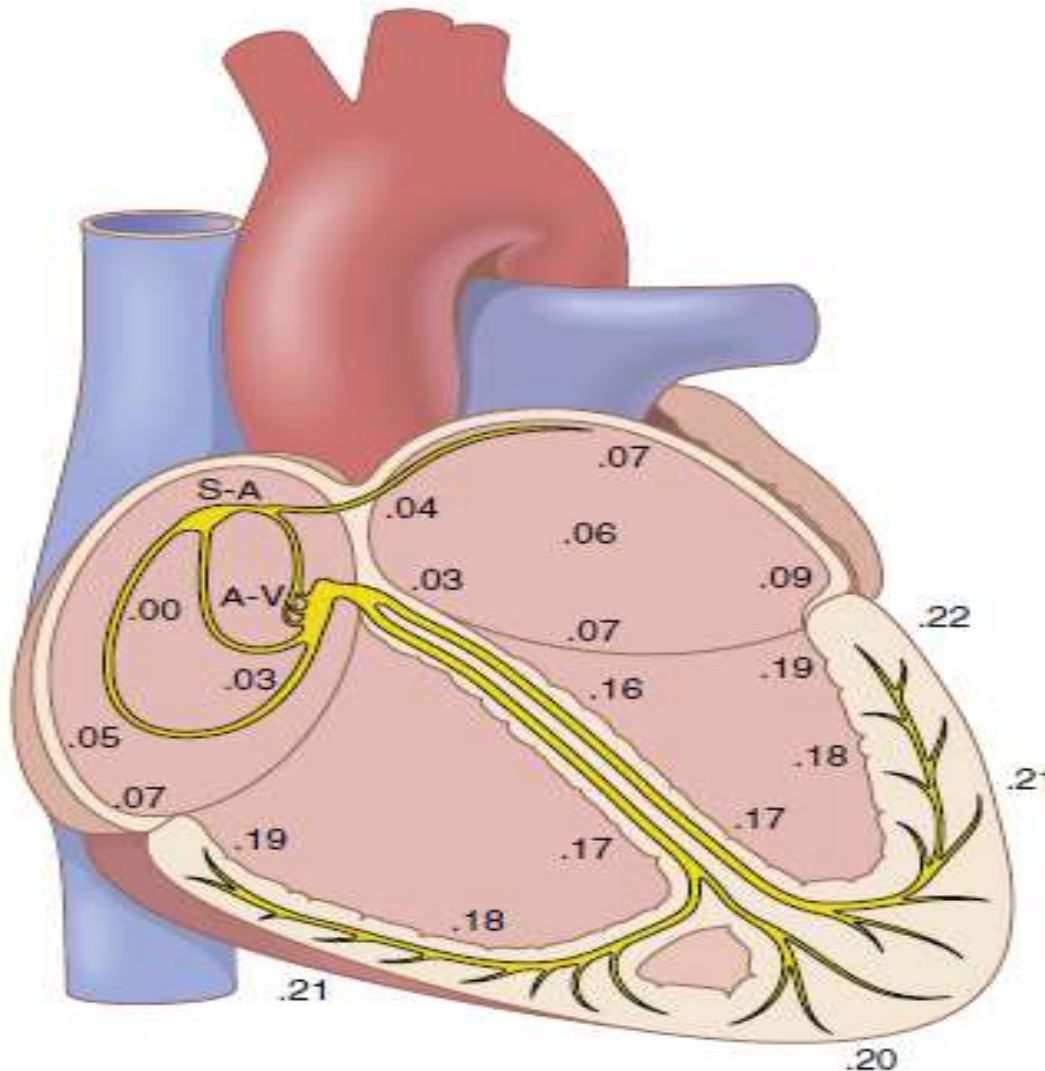
Right bundle branches

Left bundle branches

Purkinje fibers

The only site
where
action
potentials
can move
from **Atria**
to **Ventricle**

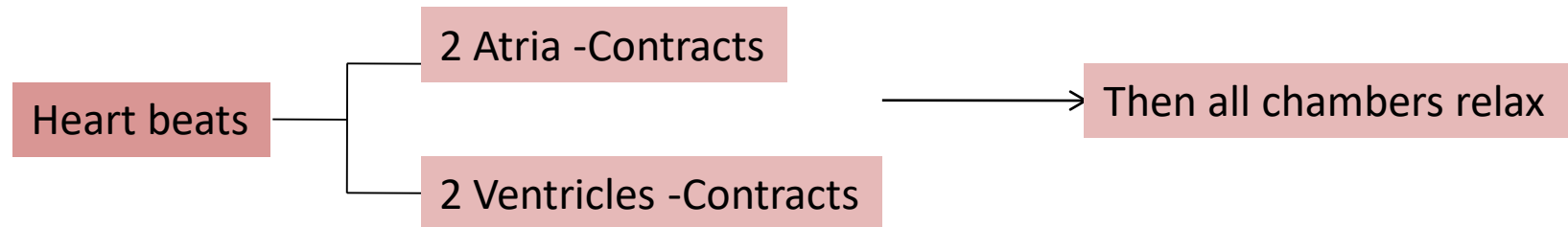
Summary of transmission of cardiac impulse through human heart



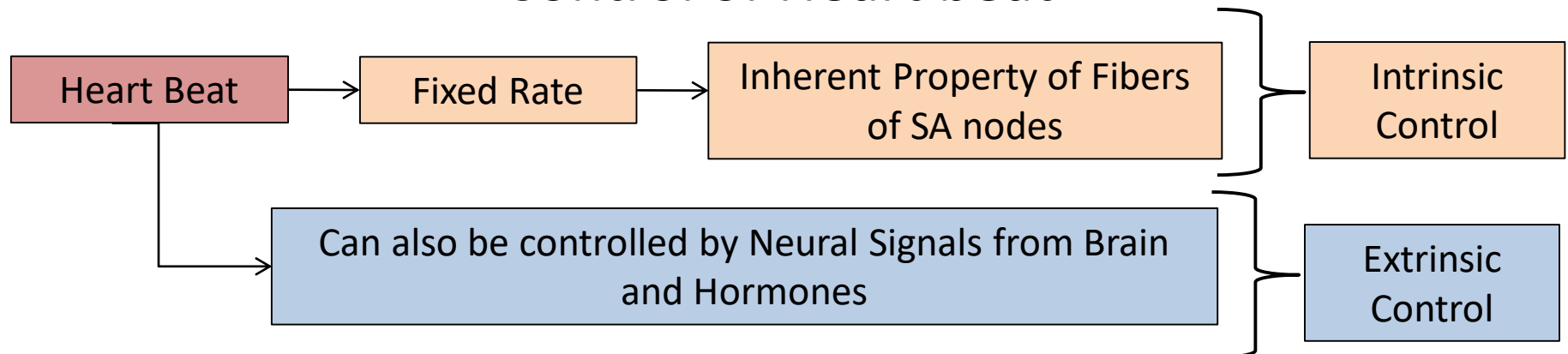
Source: John E Hall, Michael E Hall (2021), Guyton and Hall Textbook of Medical Physiology (14th Edition), Page no.130

Heart Beat

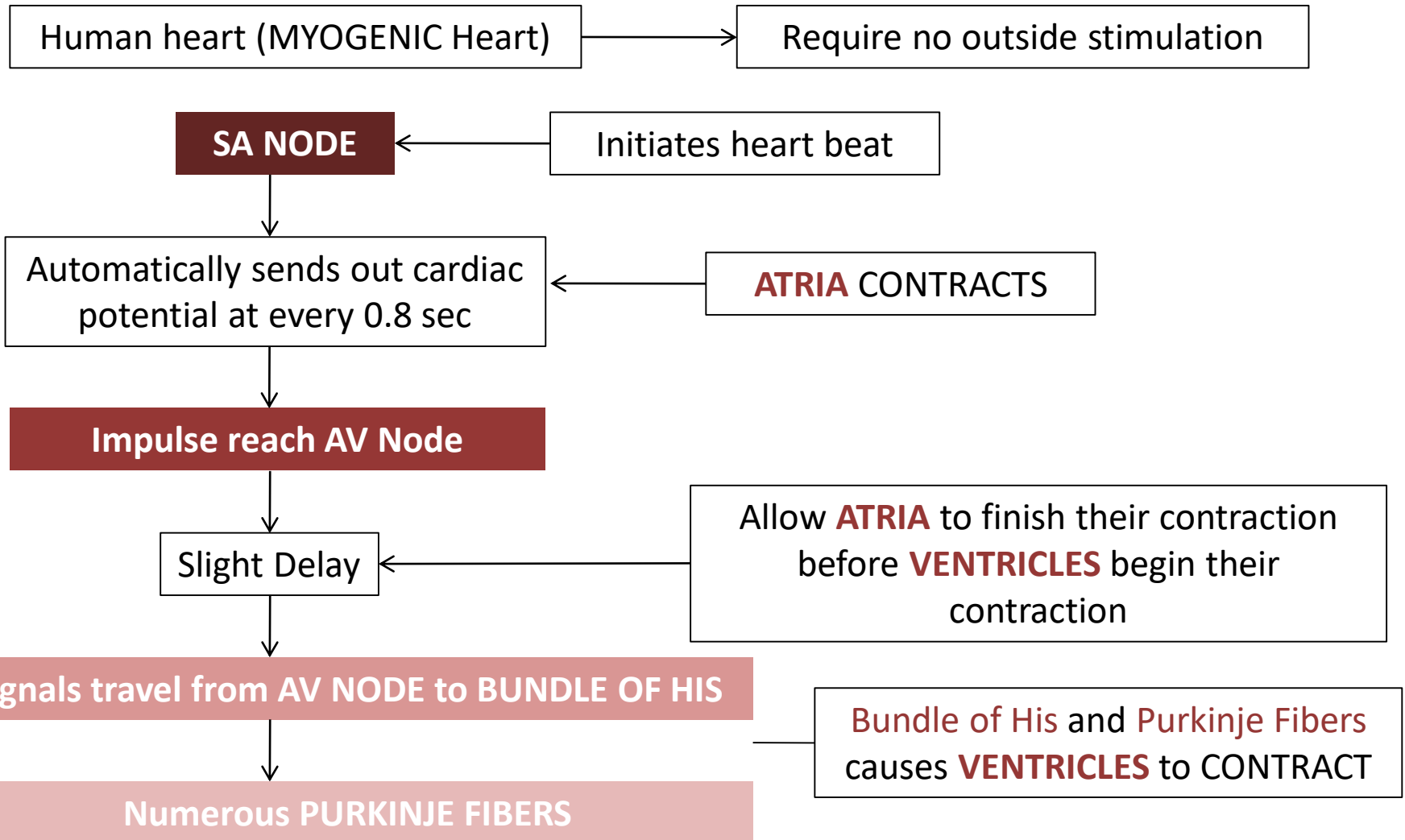
- Spontaneous rhythmic contraction and relaxation of heart
- To pump out and receive blood to and from the body
- Heart contracts/ beats= 72 times a minute each beat lasts about= 0.8 seconds



Control of Heart beat



Intrinsic control of Heart beat



Extrinsic control of Heart beat

Neural Regulation



Medulla Oblongata

Centre of Heart Beat regulation
in Brain

Neural Signals



Sympathetic nerves

Increases the rate of heartbeat strength
of ventricular contraction
Cardiac output

Hormonal Regulation



Thyroxin (Thyroid Gland)

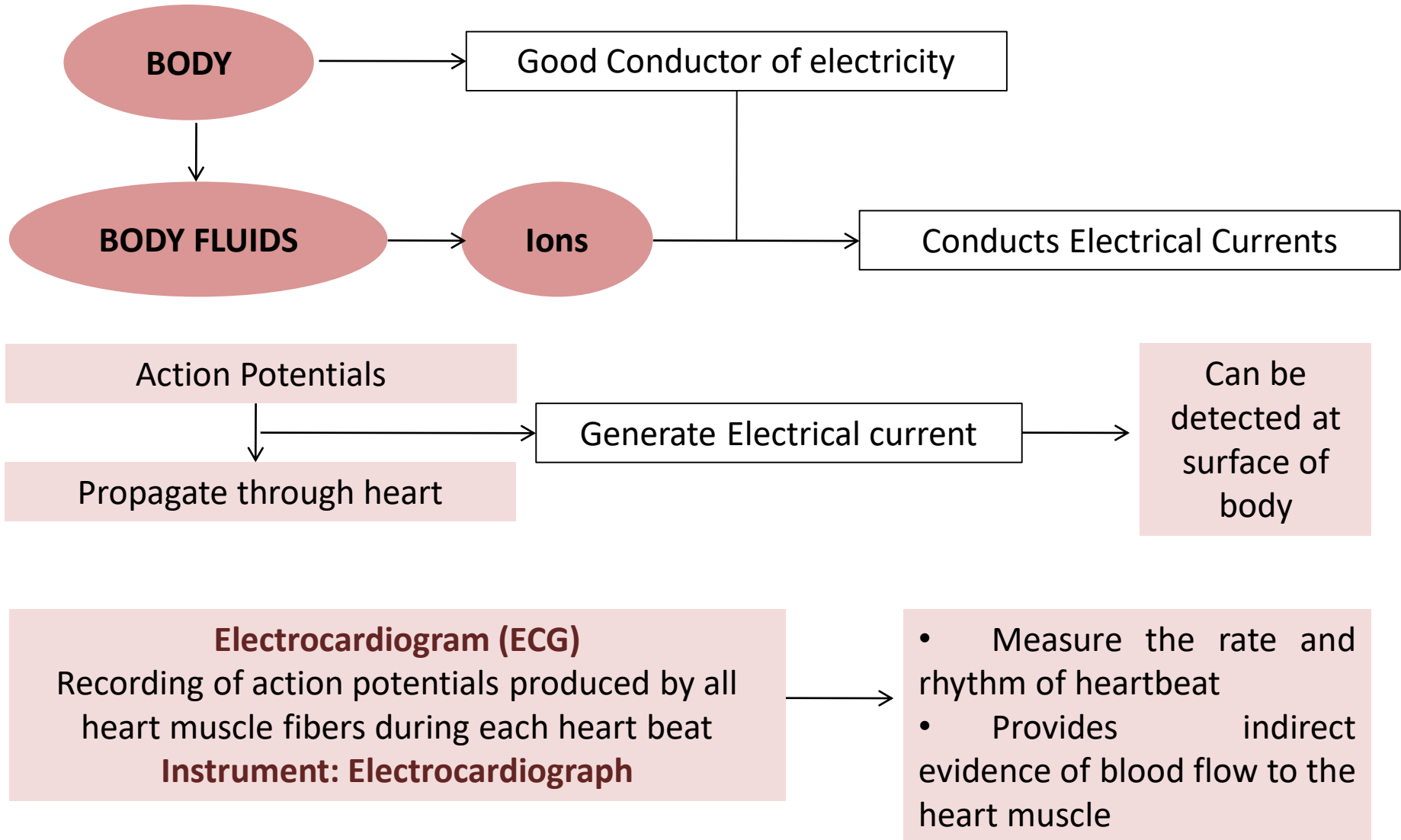
Increases heartbeat indirectly
by increasing basal metabolic
rate which requires more
oxygen

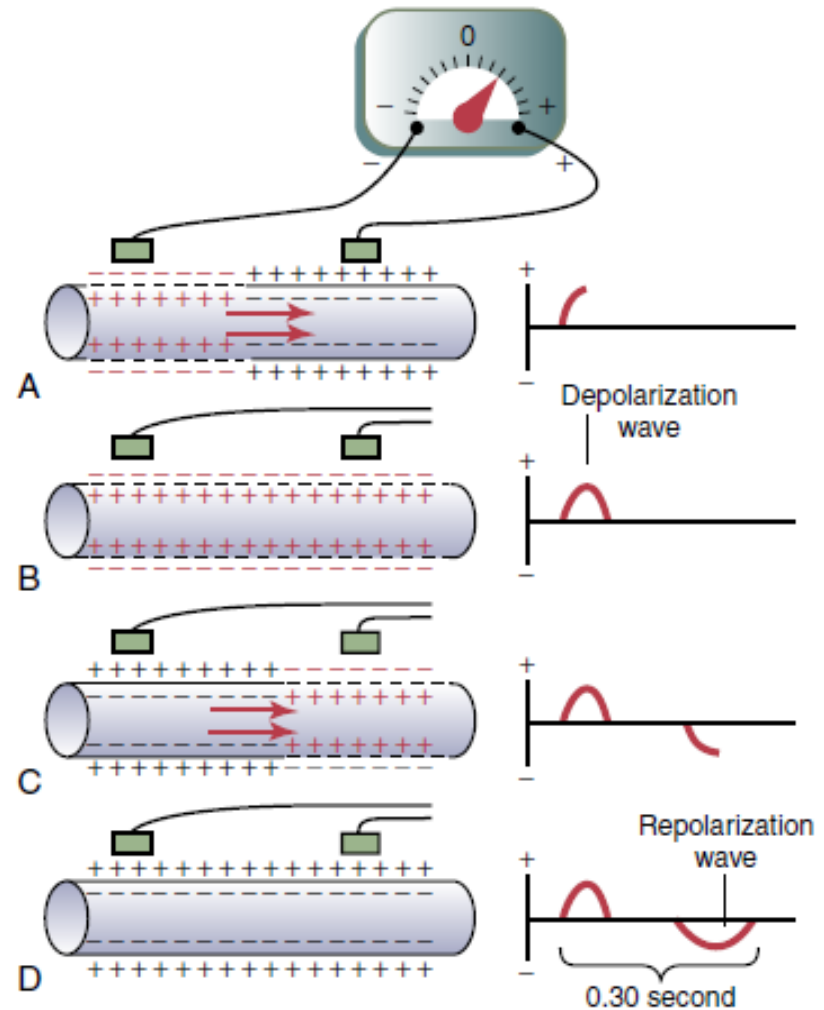
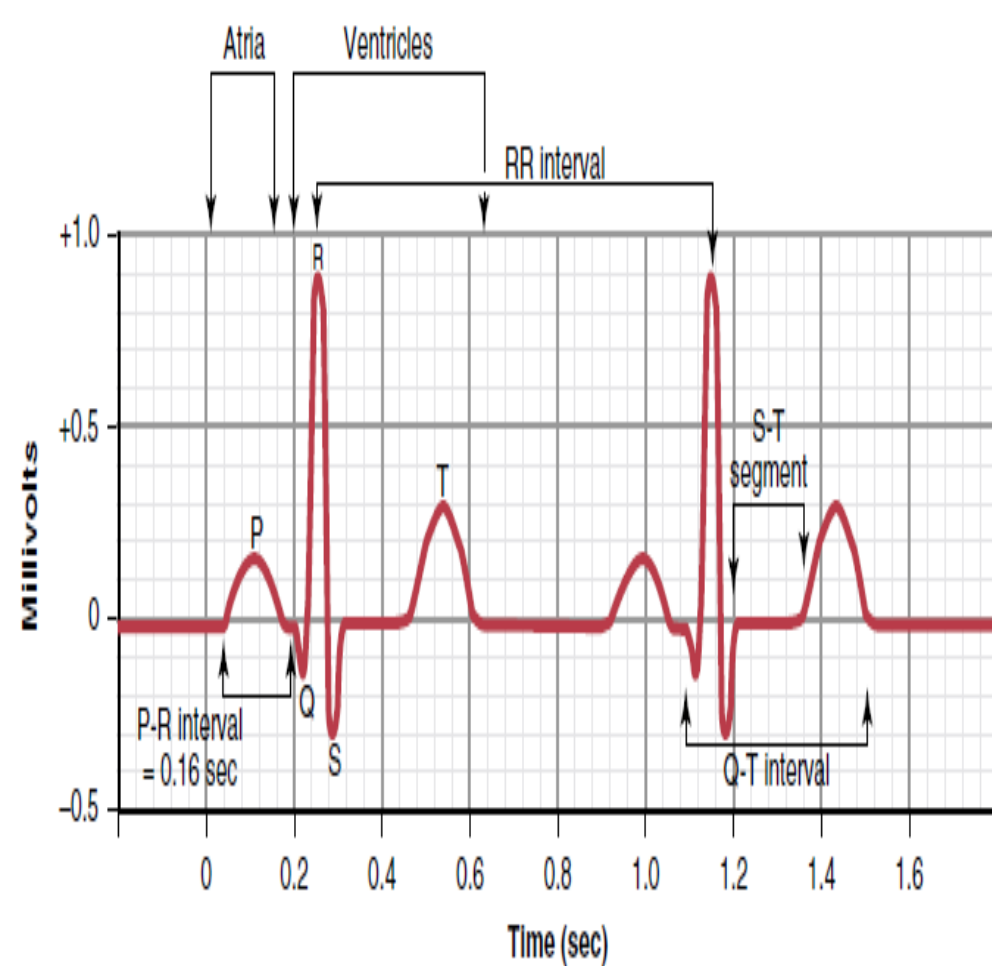


Epinephrine and nor epinephrine (Adrenal Medulla)

Epinephrine: (↑) Heartbeat
during emergency
Nor epinephrine: (↑) Heartbeat
during normal condition

Electrocardiogram





Source: John E Hall, Michael E Hall (2021), Guyton and Hall Textbook of Medical Physiology (14th Edition), Page no.136

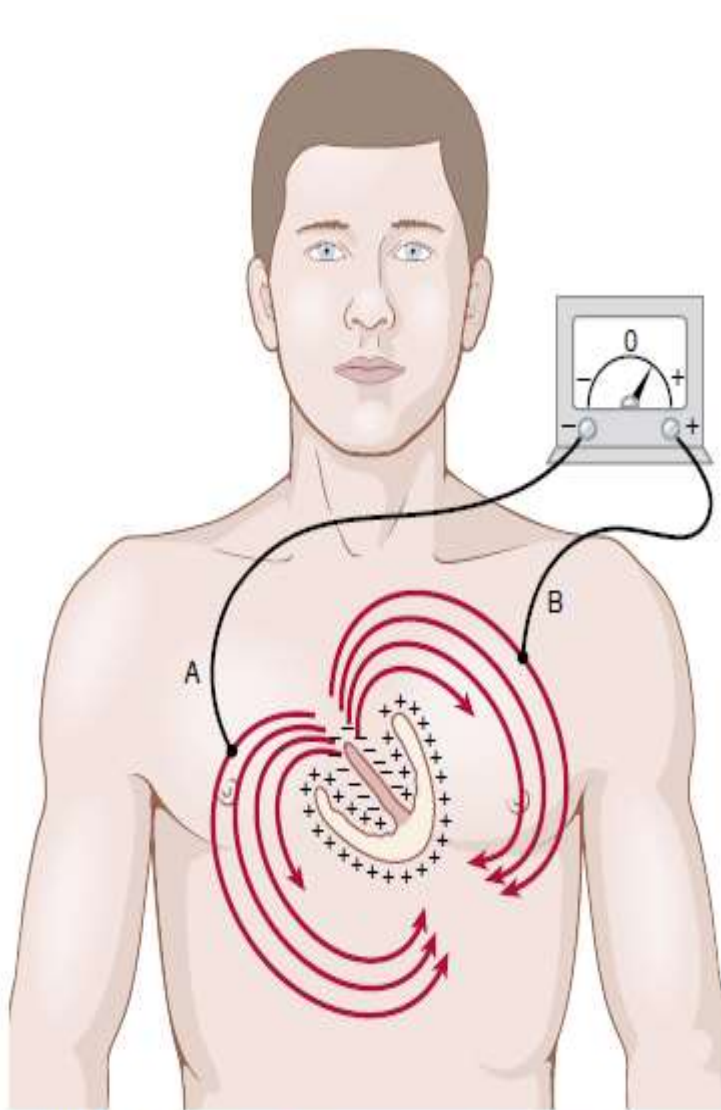


Figure 11-5. Flow of current in the chest around partially depolarized ventricles. A and B are electrodes.

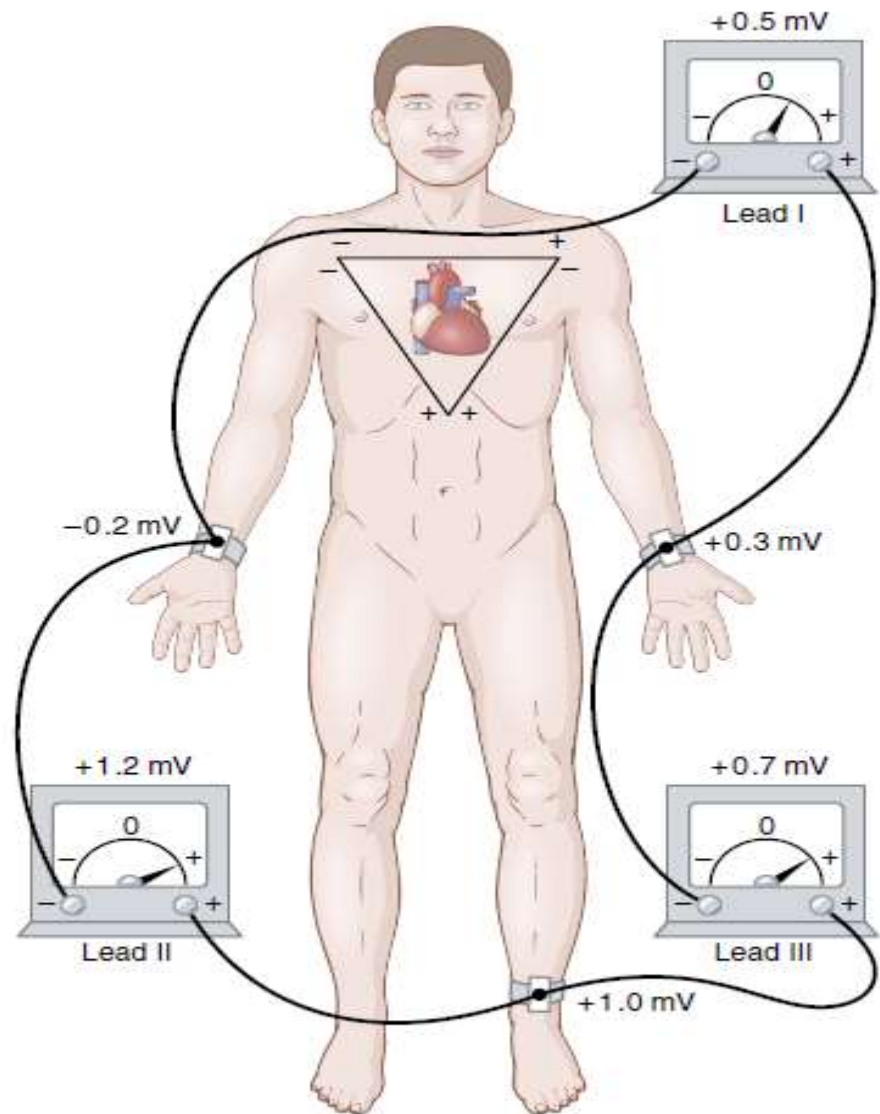


Figure 11-6. Conventional arrangement of electrodes for recording the standard electrocardiographic leads. Einthoven's triangle is superimposed on the chest.

Source: John E Hall, Michael E Hall (2021), Guyton and Hall Textbook of Medical Physiology (14th Edition), Page no.138

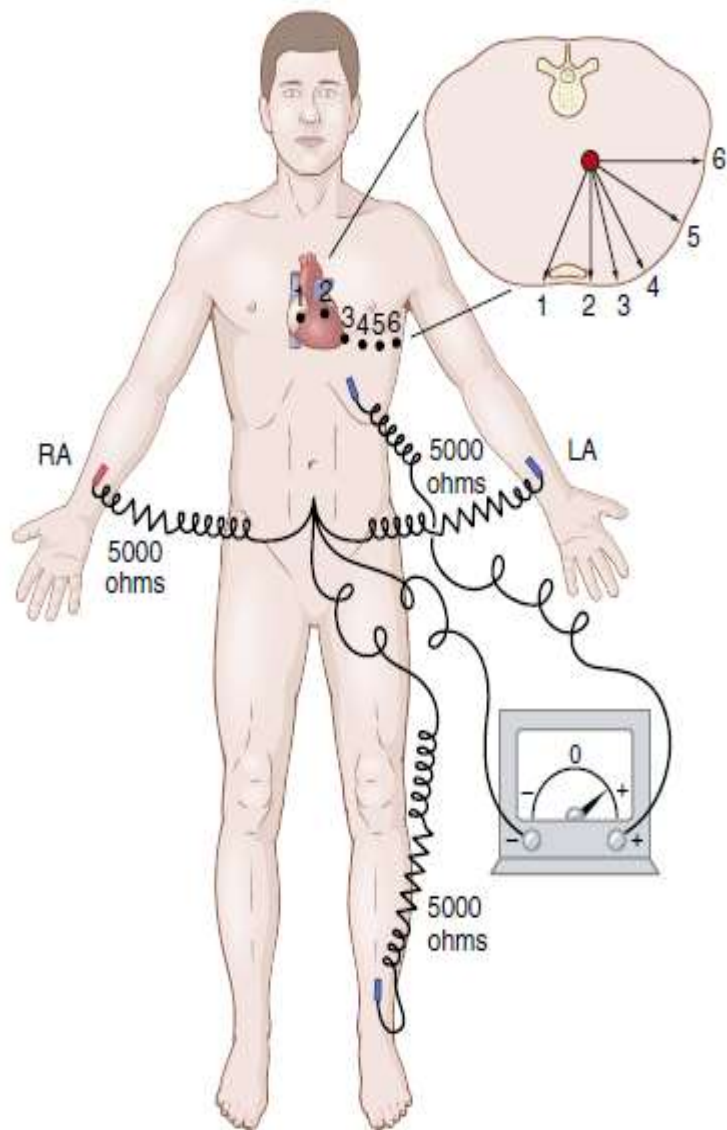


Figure 11-8. Connections of the body with the electrocardiograph for recording chest leads. LA, Left arm; RA, right arm.

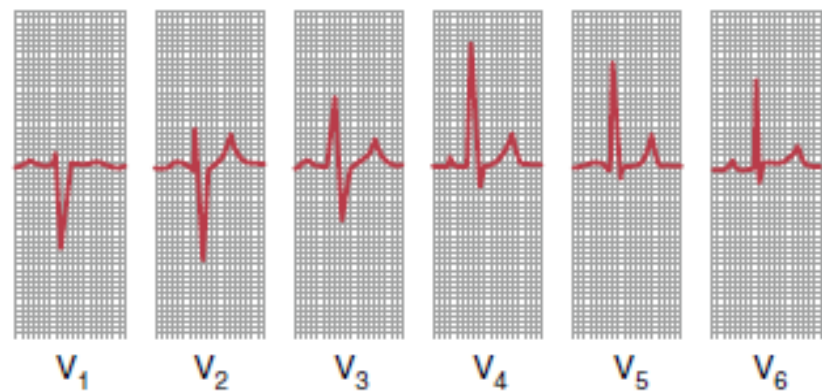


Figure 11-9. Normal electrocardiograms recorded from the six standard chest leads.

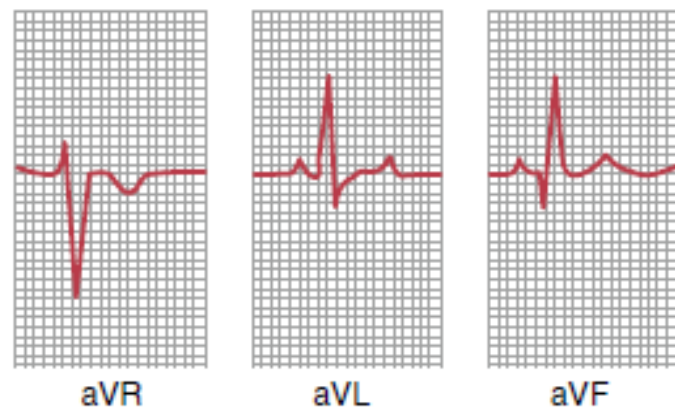
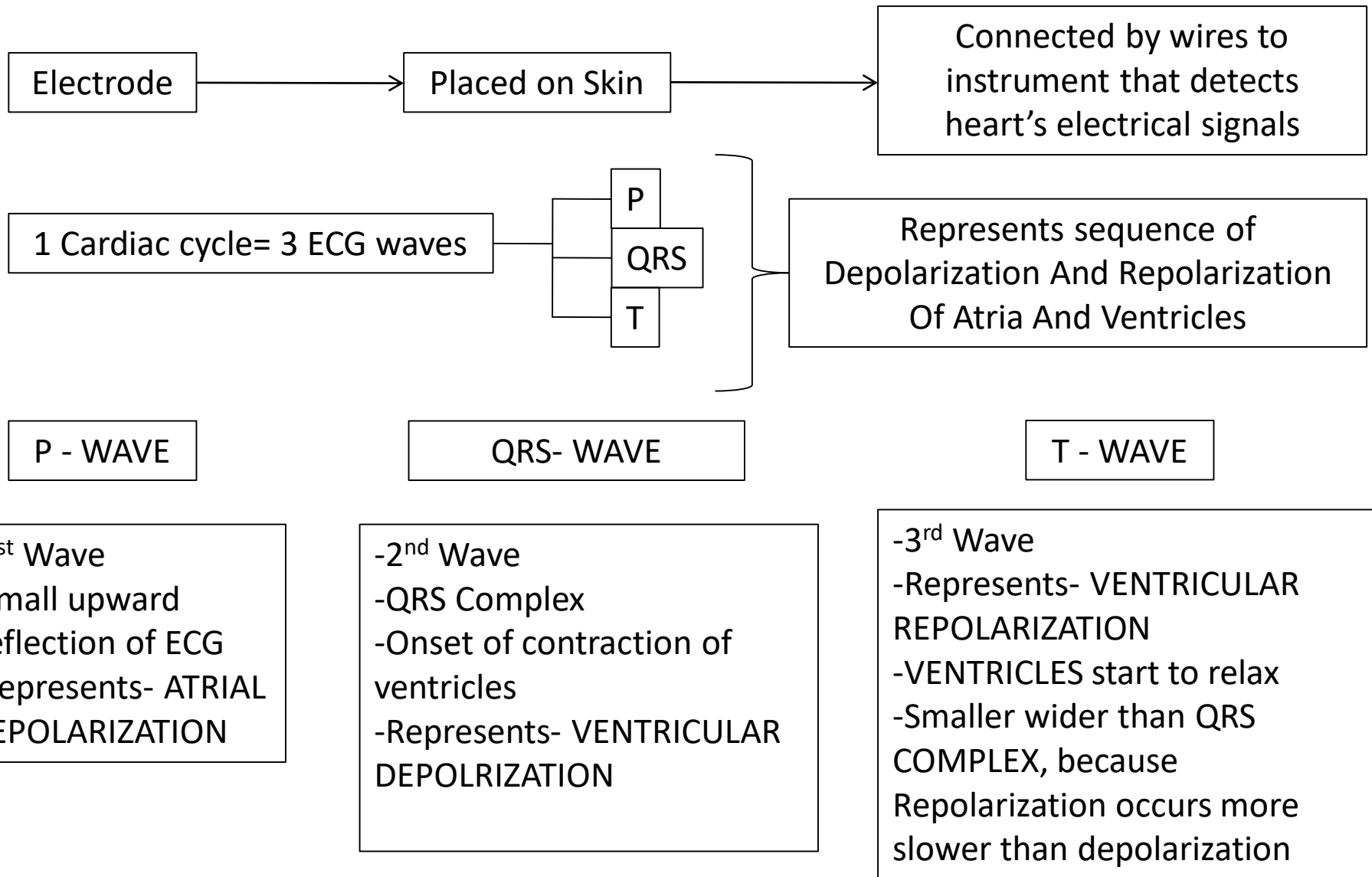


Figure 11-10. Normal electrocardiograms recorded from the three augmented unipolar limb leads.

Source: John E Hall, Michael E Hall (2021), Guyton and Hall Textbook of Medical Physiology (14th Edition), Page no.140

Operating method



P-wave

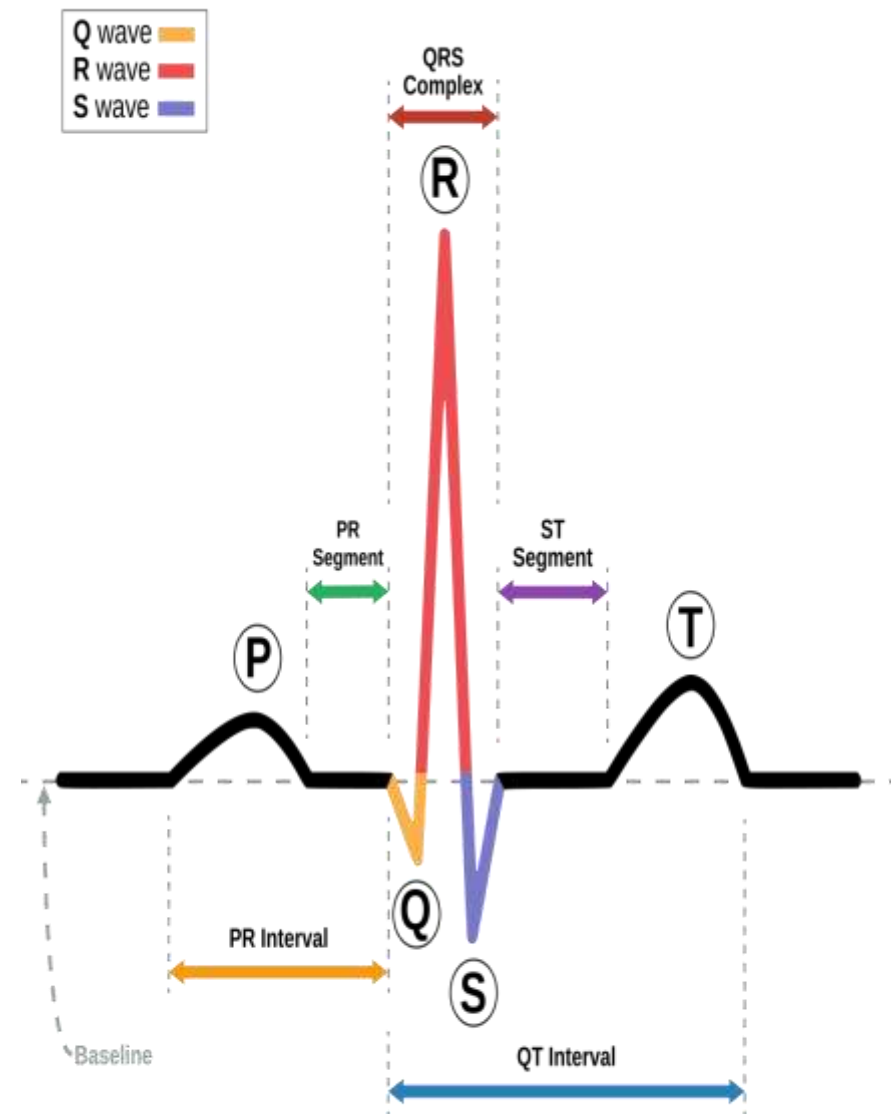
- 1st wave
- Small upward deflection of ECG
- Represents- Atrial Depolarization
- Action potential spreads to SA node throughout ATRIA
- Duration: 80-100millisecods

QRS- wave

- 2ND Wave
- QRS complex
- Onset of contraction of ventricles
- Represents- Ventricular Depolarization
- Action potential spreads into VENTRICLES
 - **Q- Wave:** 1st downward(Negative) deflection after P-wave
 - **R- Wave:** 1st upward (positive) deflection after Q-wave
 - **S- Wave:** 1st downward (negative) deflection after R-wave

T- wave

- 3rd wave
- Represents- Ventricular Repolarization
- Ventricles- starts to relax
- Smaller wider than QRS complex. Because Repolarization occurs more slowly than depolarization



Source:

<https://en.wikipedia.org/wiki/Electrocardiography>

PR interval

- Include P wave and PR segment
 - **PR-Segment:** represents time taken by AV node to conduct the impulse
 - **ST-Segment:** represents time gap between depolarization and repolarization in the ventricles. This segment lies between QRS and T
 - **PR interval**
 - Shortens- at high heart rates (eg. During/ due to exercise)
 - Increases- at lower heart rates (eg. During sleep)

QT interval

- Measured from beginning of QRS complex to end of T wave
- Represents time between activation of electric activity in ventricles and their return to resting state

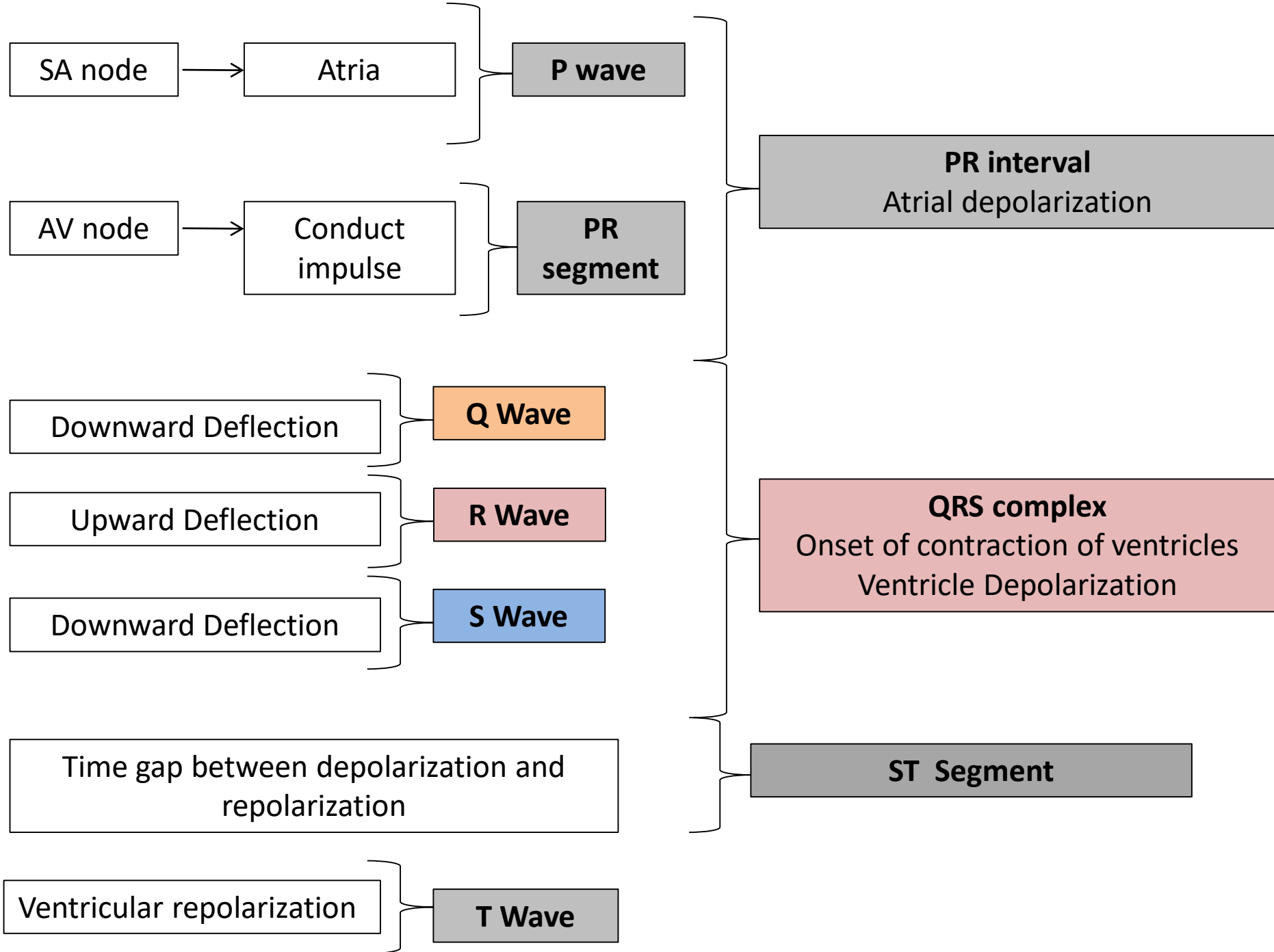
Overall,

P -Wave: atrial depolarization

QRS- Complex: onset of ventricular depolarization

T- wave: ventricular repolarization

PQ interval: conduction time from beginning of atrial excitation to beginning of ventricular excitation.

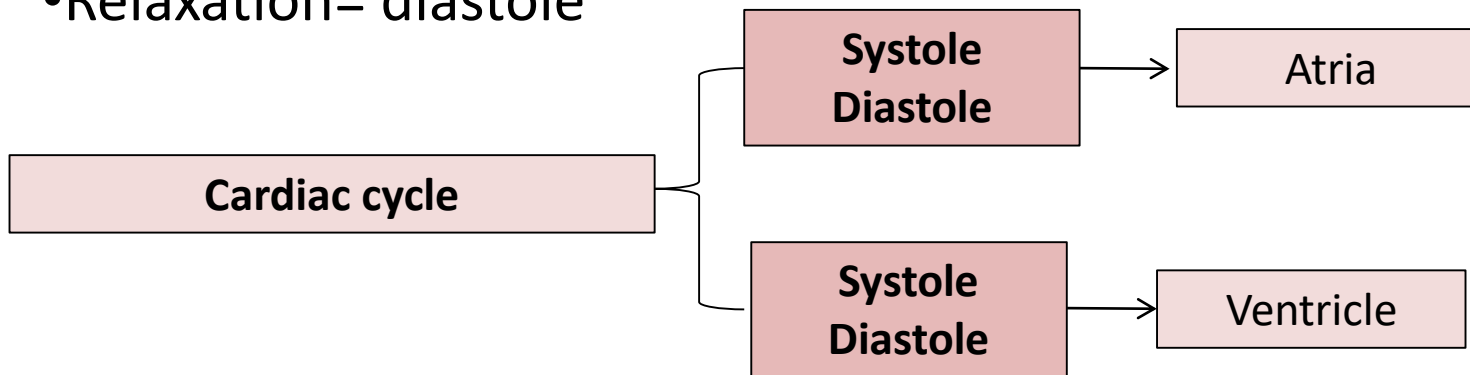


Abnormalities and it indicates,

Abnormalities	Indication
P wave: larger	Enlargement of Atrium
Q wave: larger	Myocardial infraction
R wave: larger	Enlarged ventricles
T wave: flat	Insufficient oxygen (coronary artery disease)
T wave: elevated	Hyperkalemia (high blood K level)

Cardiac cycle

- Cycle of events- occur in single heart beat
- Repeating pattern of contraction and relaxation of heart
- Contraction= systole
- Relaxation= diastole



Heart Rate= 75 beats/ min = cardiac cycle= 0.8 seconds

Atrial systole:

- Atria contracts
- Ventricles relaxed
- Atrial depolarization
- Open AV valve



End of Atrial Systole:

End of ventricular diastole



Ventricular systole:

- Ventricle contracts
- Atria relaxes
- Pressure ventricles rises
- Closure of AV valve



Isovolumetric contraction:

Constant volume and length



Ventricular ejection:

Ejection of blood from right and left ventricles into pulmonary trunk and aorta respectively

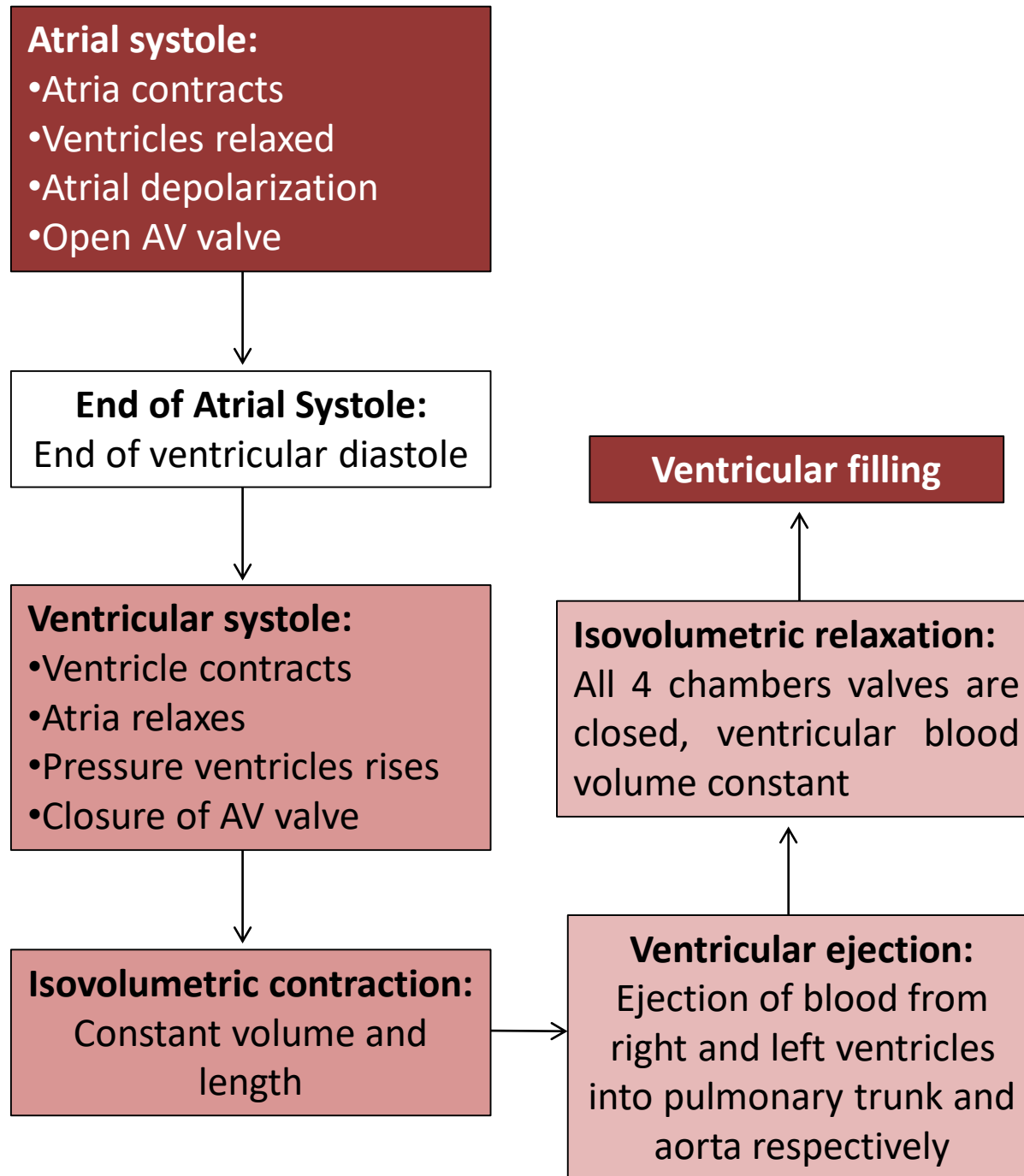


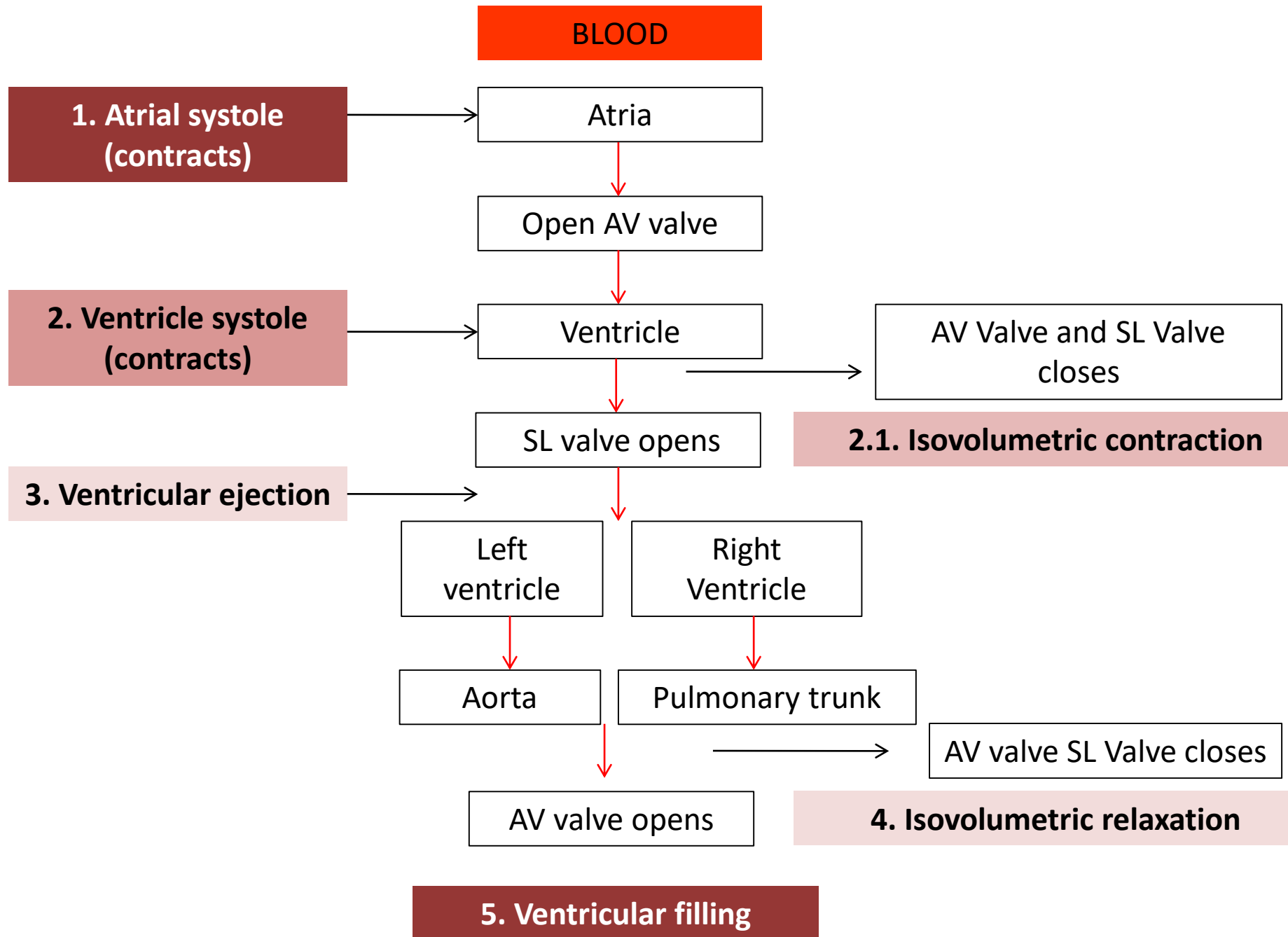
Isovolumetric relaxation:

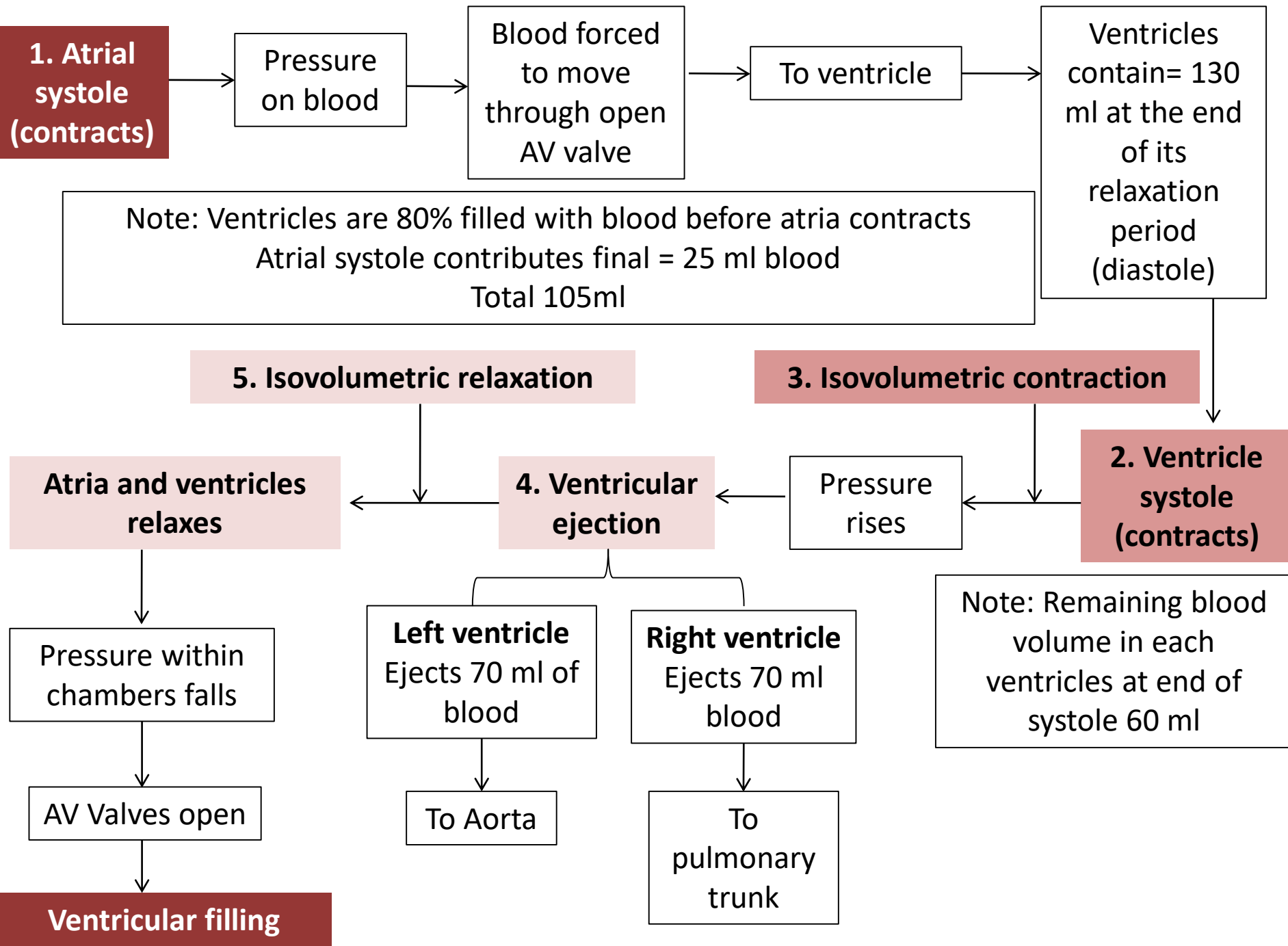
All 4 chambers valves are closed, ventricular blood volume constant

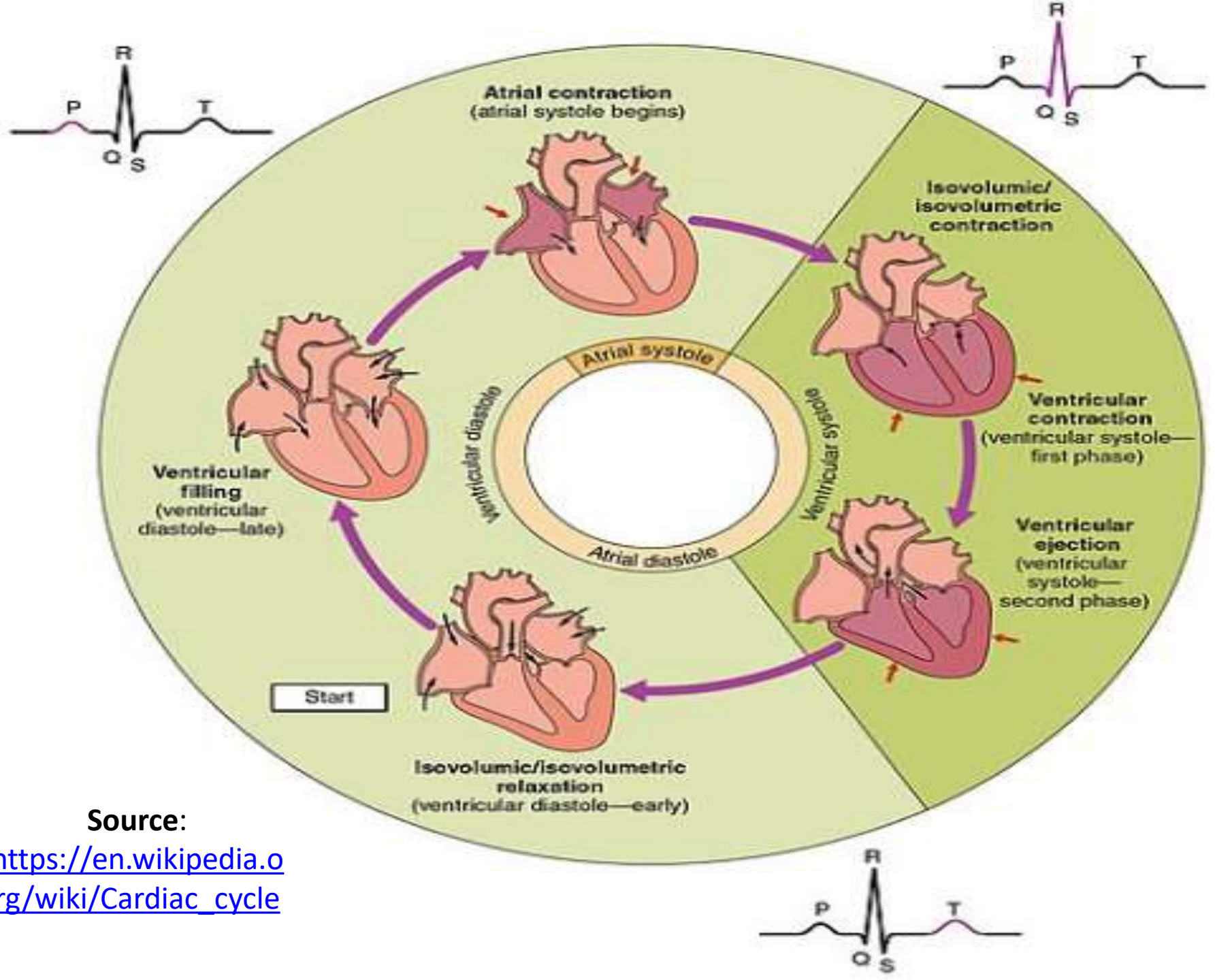


Ventricular filling



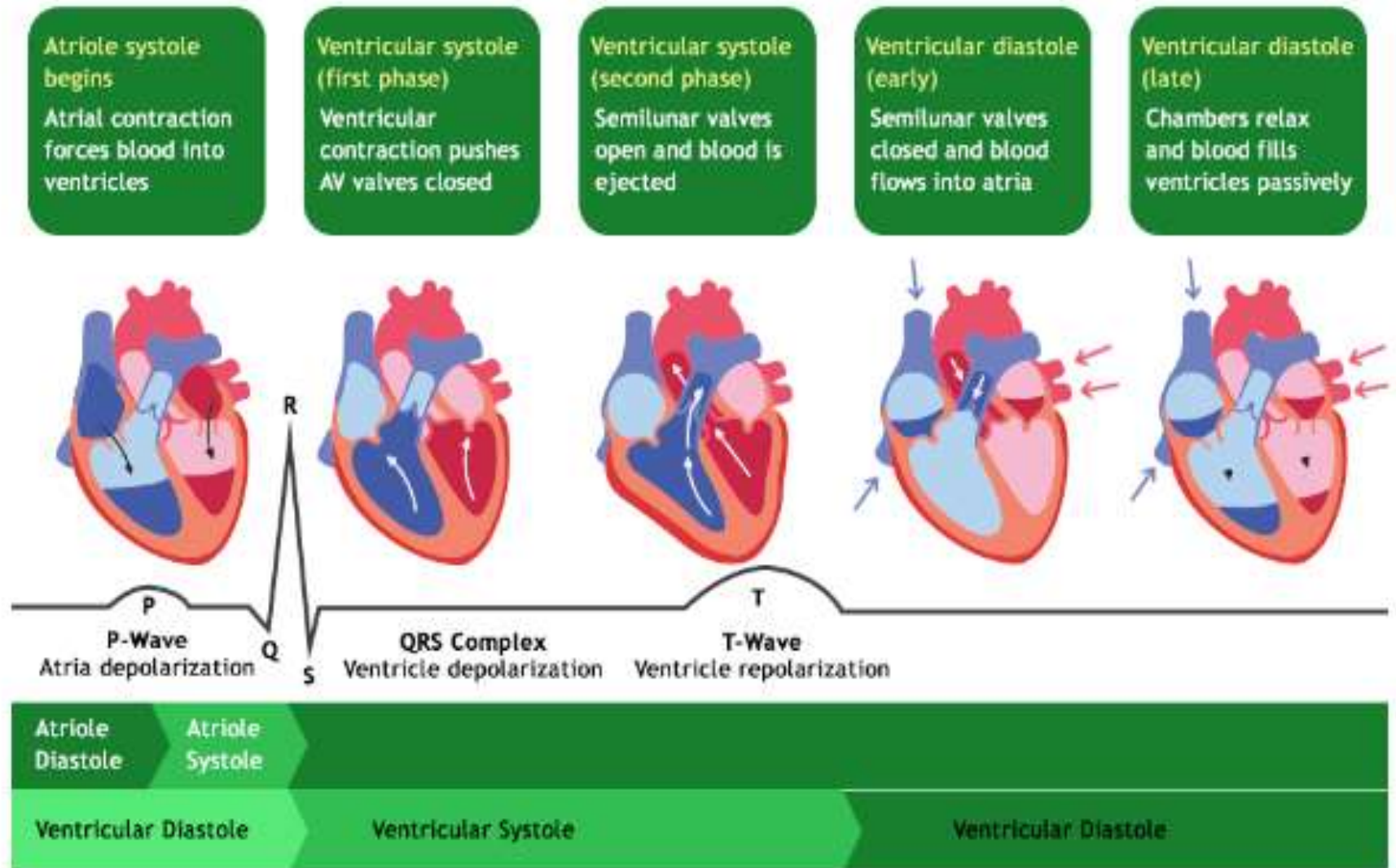




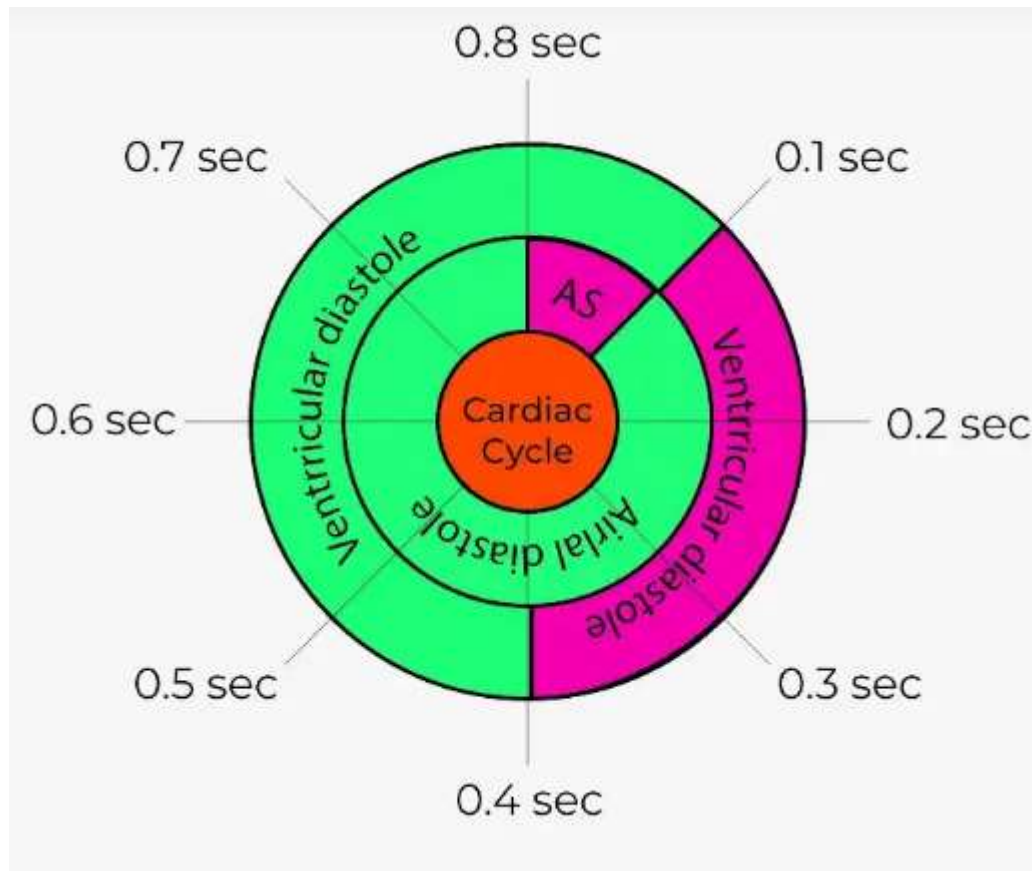


Source:

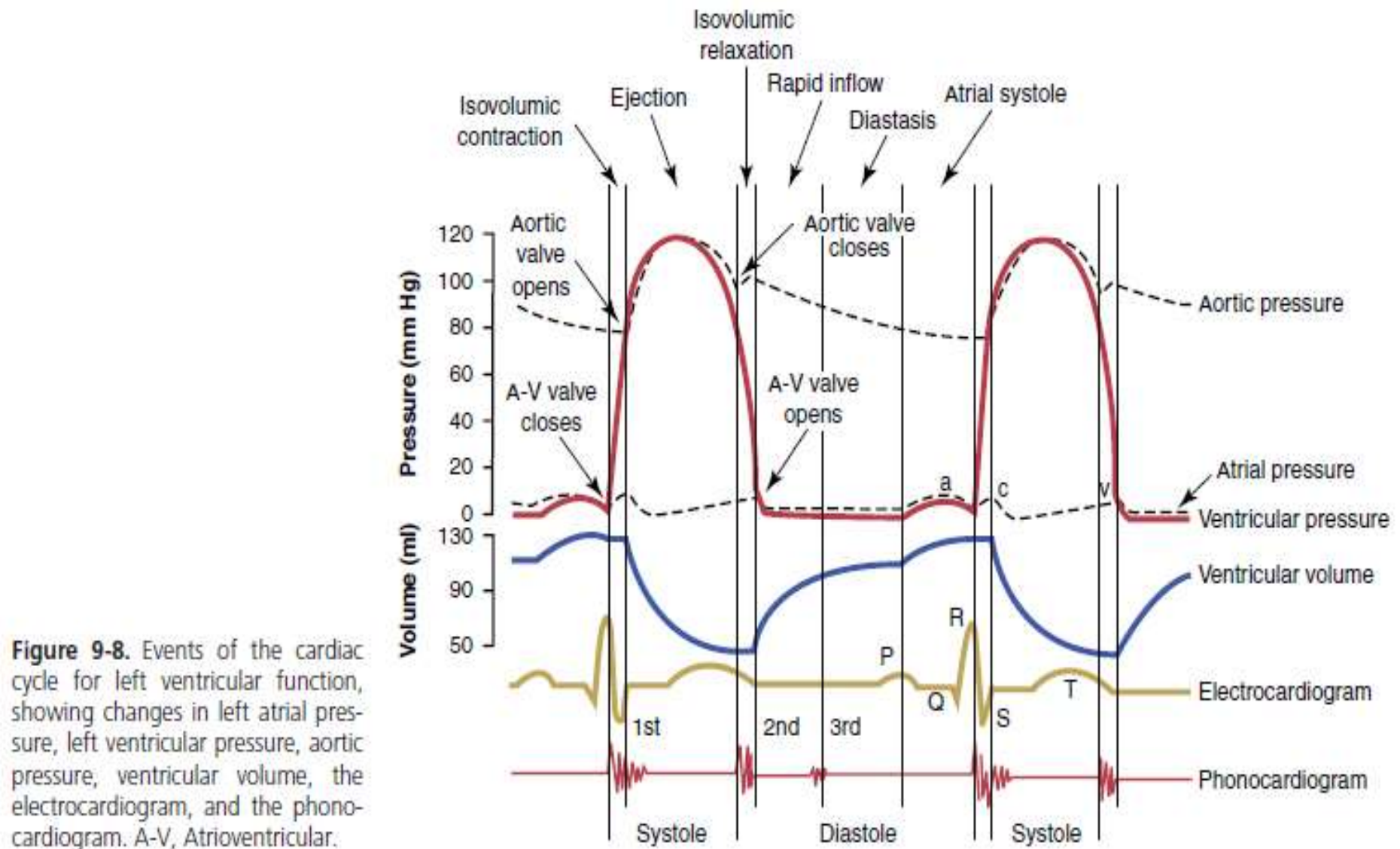
https://en.wikipedia.org/wiki/Cardiac_cycle



Source: <https://www.geeksforgeeks.org/biology/cardiac-cycle-phase-diagram/>



Source: <https://www.geeksforgeeks.org/biology/cardiac-cycle-phase-diagram/>



Source: John E Hall, Michael E Hall (2021), Guyton and Hall Textbook of Medical Physiology (14th Edition), Page no.118

Heart sound

Cardiac cycle= 4 sounds

In normal heart- only first and second heart sounds are loud and can be heard through stethoscope

1st sound

Low pitch
Soft
Relatively long
Sounding= LUB

- Closure of AV valve
- Ventricles contract at systole

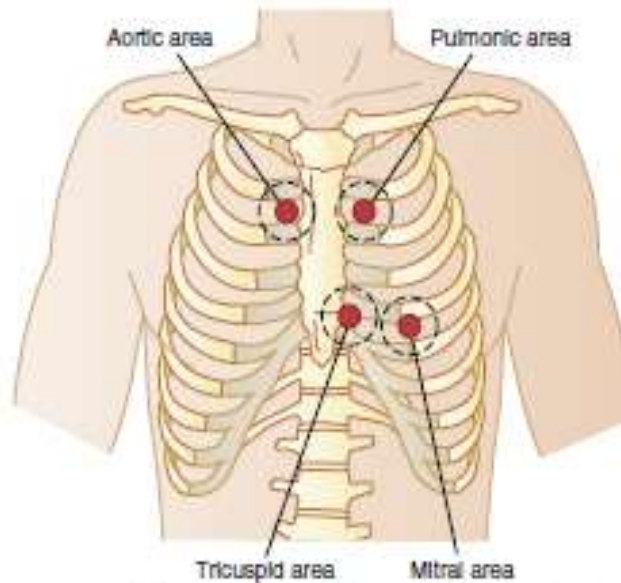


Figure 23-2 Chest areas from which sounds from each valve are heard best.

2nd sound

High Pitch
Sharp
Short
sounding= DUB

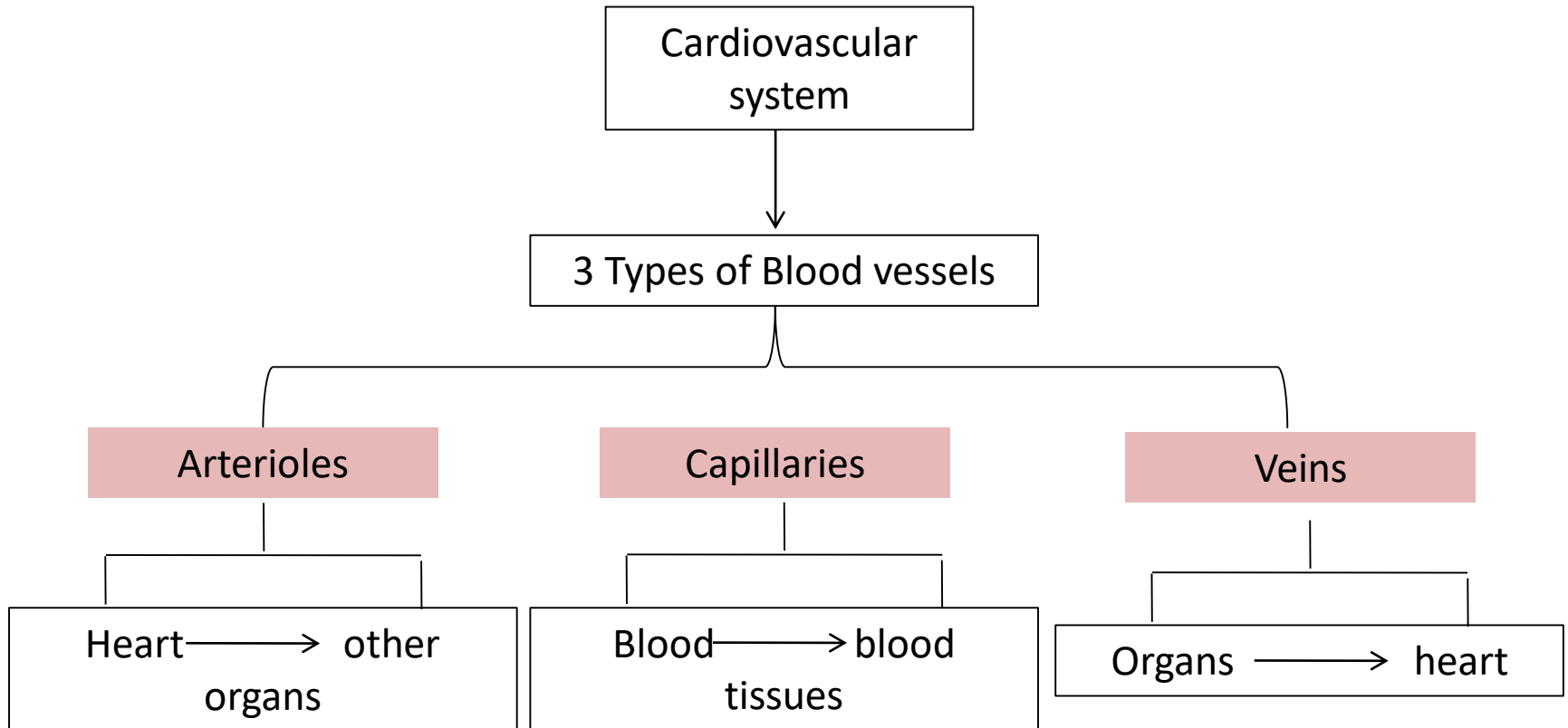
- Closure of SL valve
- Ventricles relax at beginning of diastole

Cardiac output

Volume of blood pumped per minute by each ventricle

- **Heart Rate** = 72 cardiac cycles/ minute
- **Duration of cardiac cycle**= 0.8 secs
- During cardiac cycle, ventricles pumps out approx. 70 ml of blood= **Stroke Volume**
- Stroke volume $\times$ heart rate= cardiac output
 $70(\text{ml/Beat}) \times 72(\text{beats/ min}) = 5040\text{ml/min}$

Blood vessels



Basic structure of blood vessels

Wall of blood vessels= 3 layers (tunics)

Epithelial inner lining
(TUNICA INTERNA)

Middle layer
(TUNICA MEDIA)

Outer connective tissue
(TUNICA EXTERNA)

Intima

Inner lining
Innermost layer
Simple squamous epithelium
endothelium

Muscular

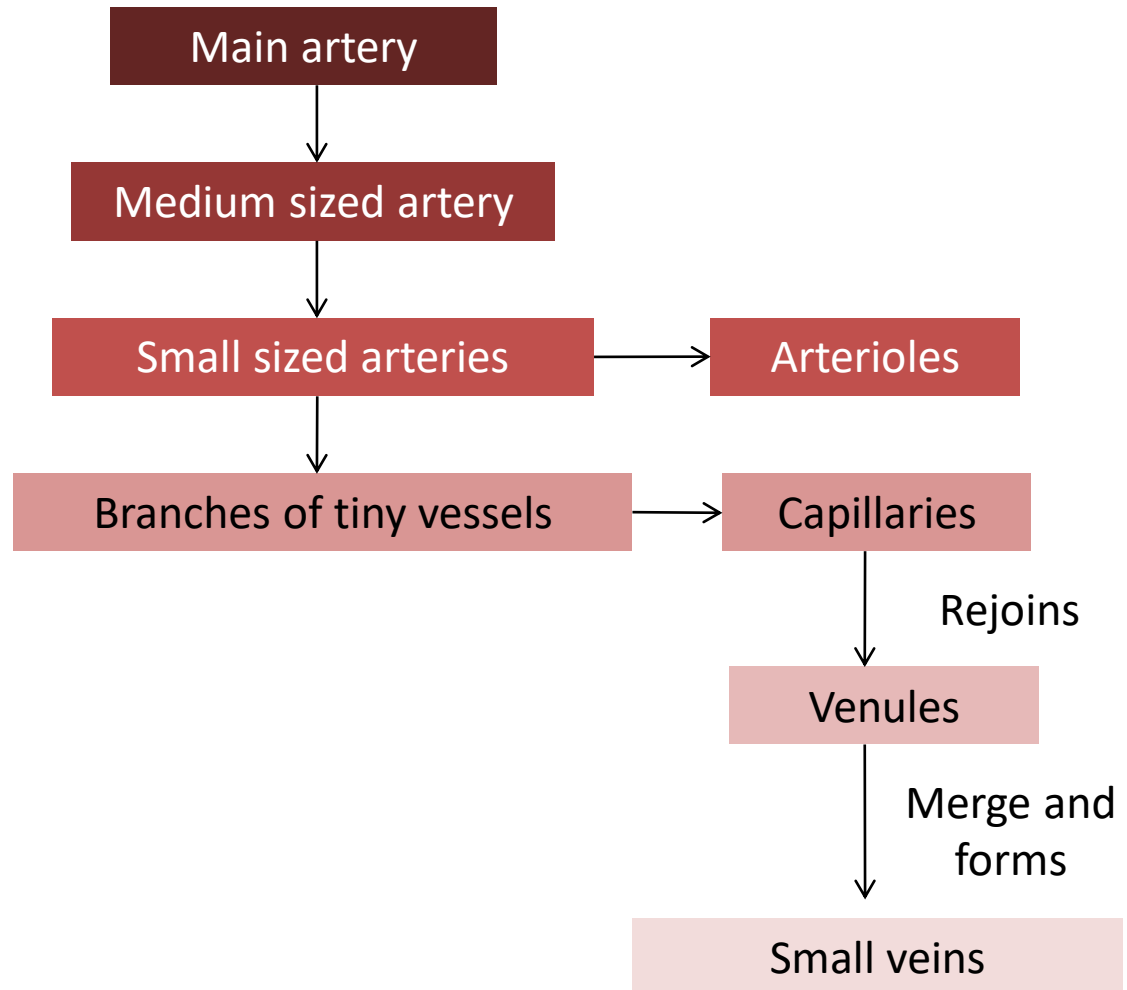
Middle layer
Intermediate layer
Smooth muscle
Displays greatest
variation among
different vessel types

Externa

Outer lining
Outermost layer
Elastic and collagen fibres

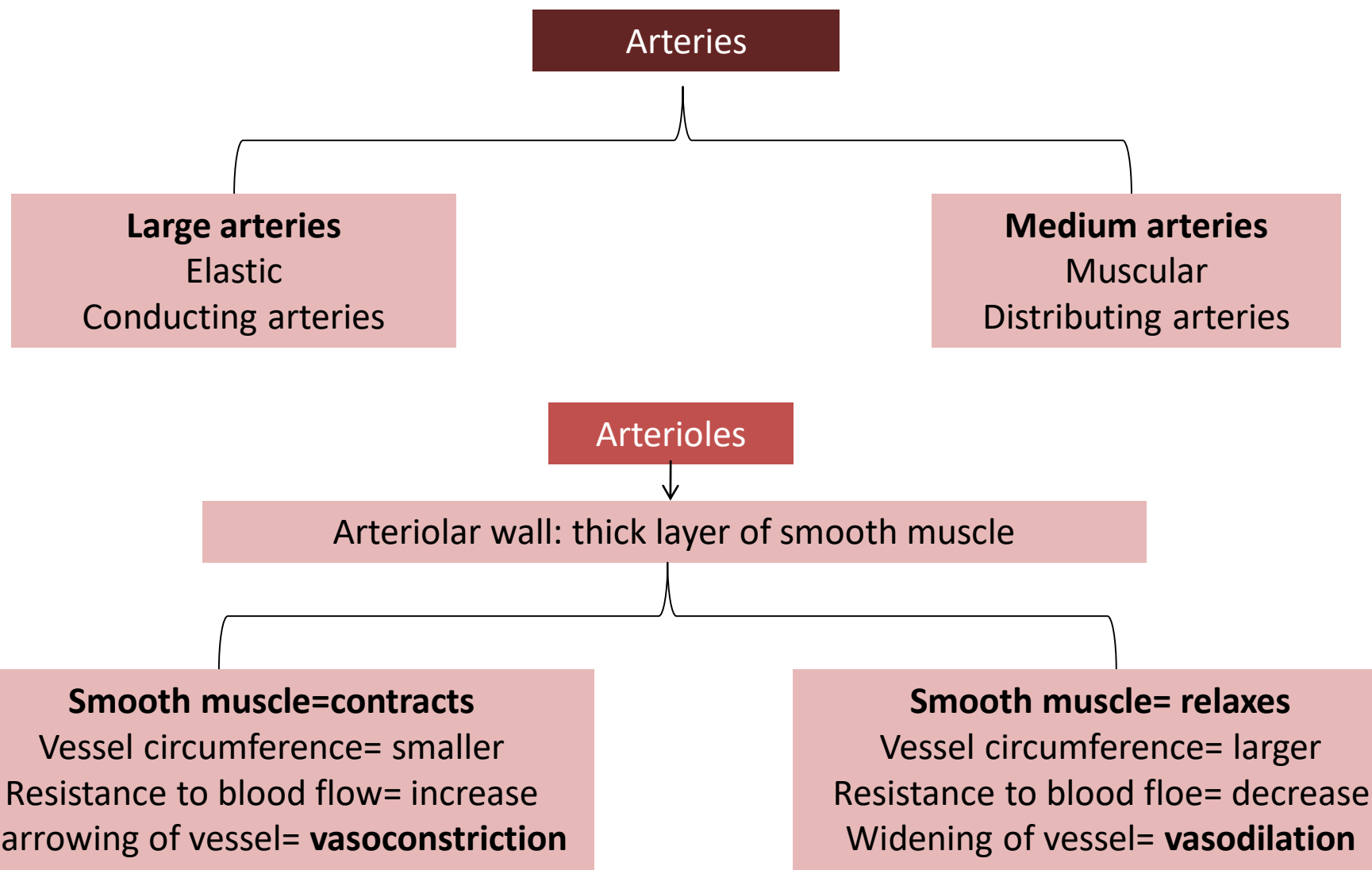
Arteries (arterioles)

- Carry blood away from heart
- Large, elastic, arteries leave the heart
- Allow stretching and absorbs pressure



Contind...

Arteries



```
graph TD; Arteries --> LargeArteries[Large arteries<br/>Elastic<br/>Conducting arteries]; Arteries --> MediumArteries[Medium arteries<br/>Muscular<br/>Distributing arteries]; Arterioles --> ArteriolarWall[Arteriolar wall: thick layer of smooth muscle]; ArteriolarWall --> SmoothContracts[Smooth muscle=contracts<br/>Vessel circumference= smaller<br/>Resistance to blood flow= increase<br/>Narrowing of vessel= vasoconstriction]; ArteriolarWall --> SmoothRelaxes[Smooth muscle= relaxes<br/>Vessel circumference= larger<br/>Resistance to blood flow= decrease<br/>Widening of vessel= vasodilation];
```

Large arteries
Elastic
Conducting arteries

Medium arteries
Muscular
Distributing arteries

Arterioles

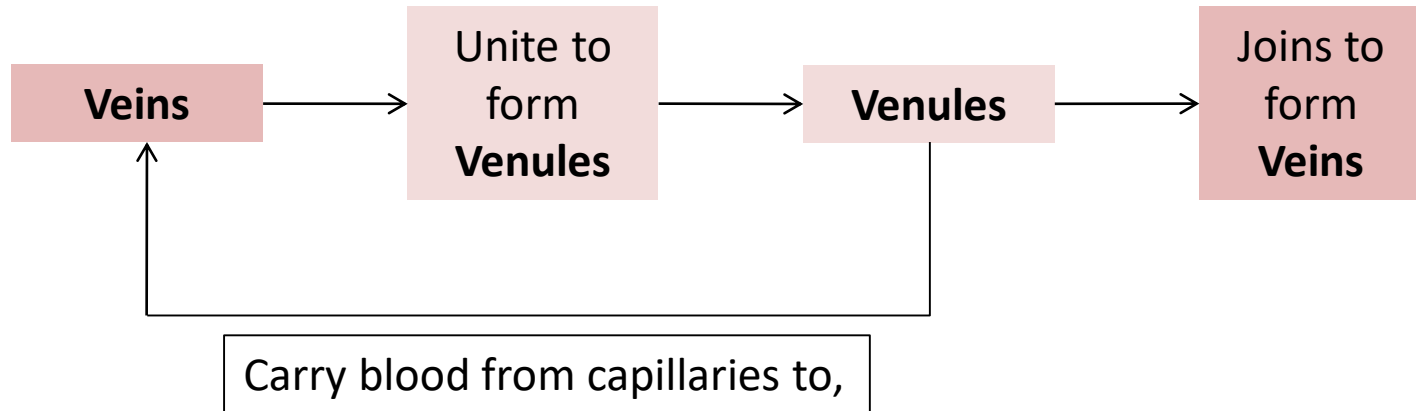
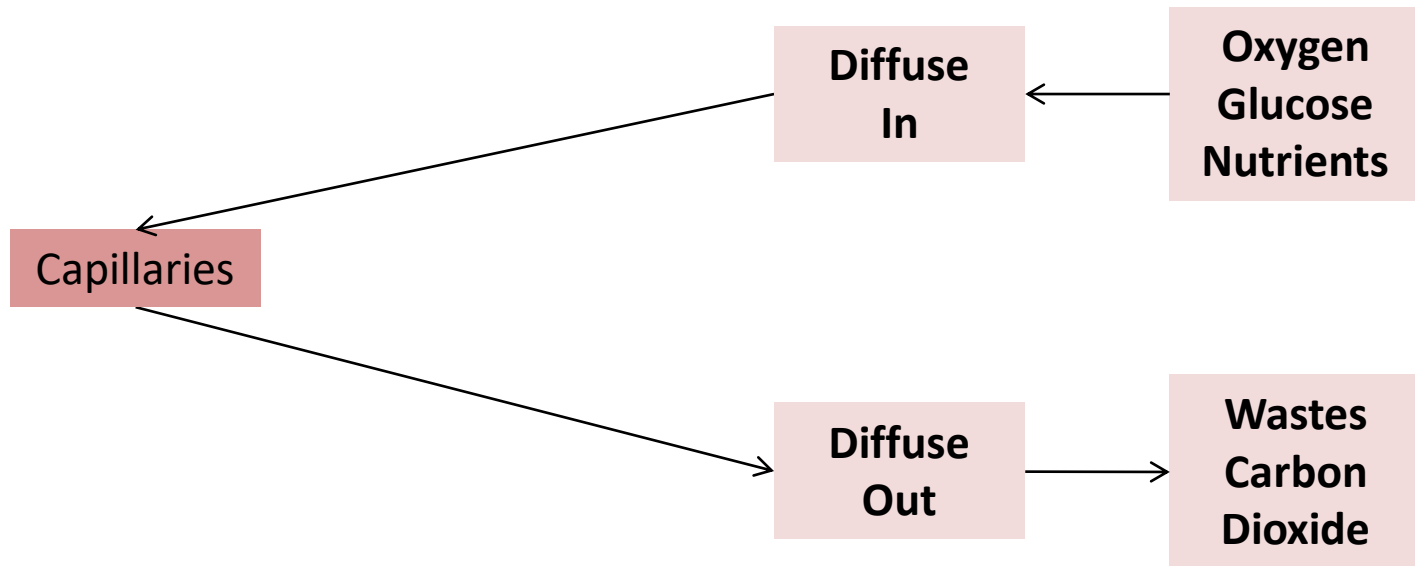
Arteriolar wall: thick layer of smooth muscle

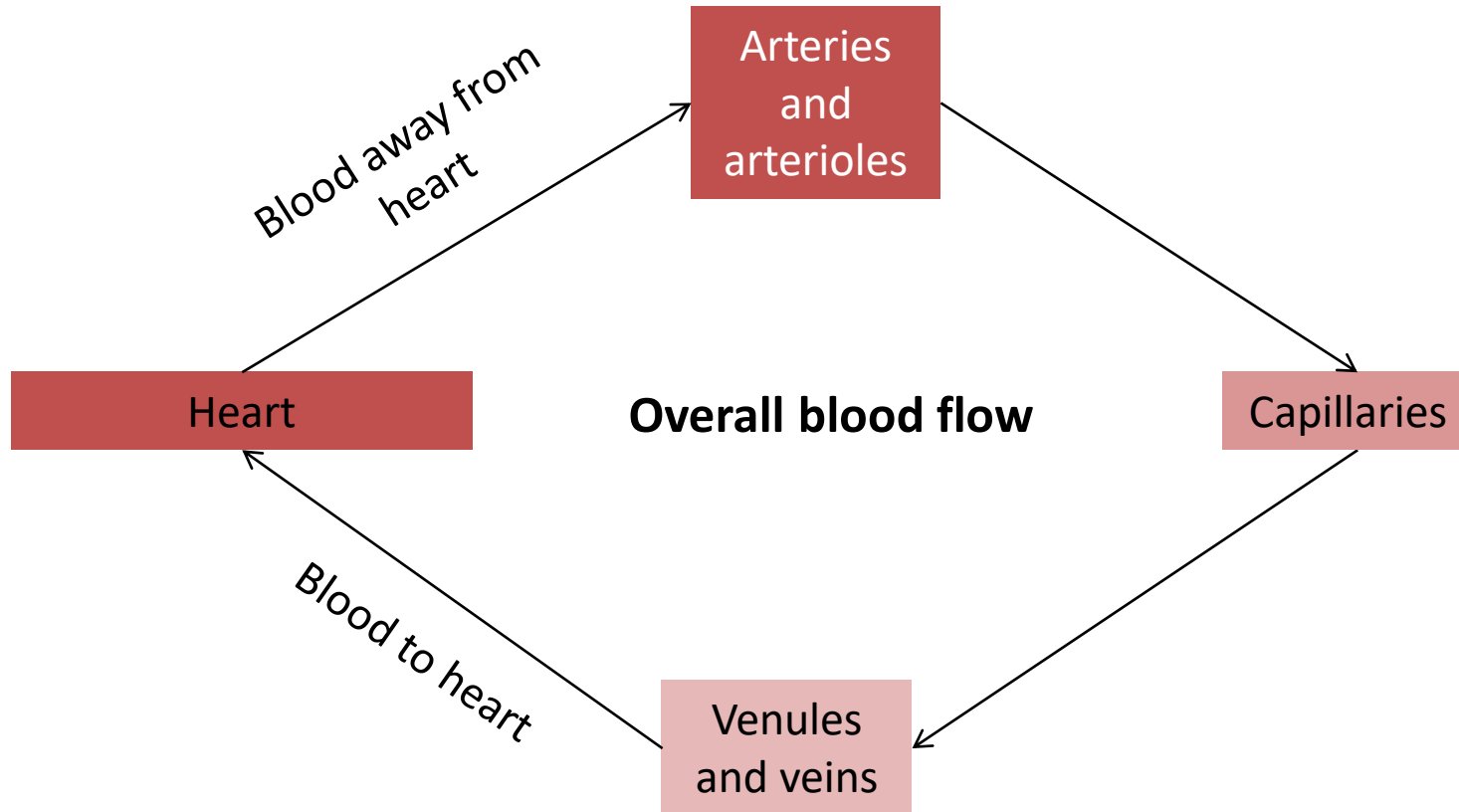
Smooth muscle=contracts
Vessel circumference= smaller
Resistance to blood flow= increase
Narrowing of vessel= **vasoconstriction**

Smooth muscle= relaxes
Vessel circumference= larger
Resistance to blood flow= decrease
Widening of vessel= **vasodilation**

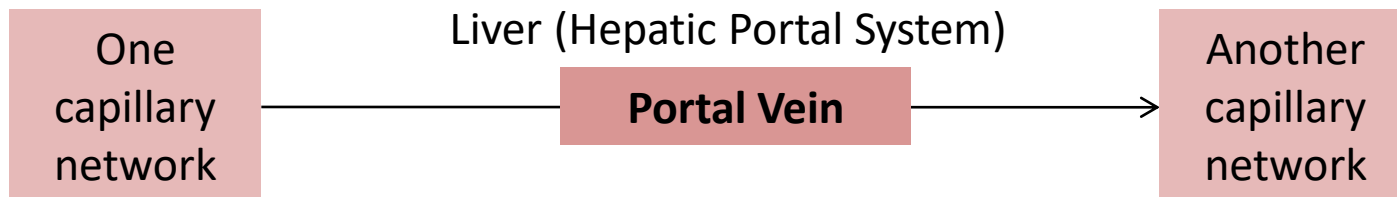
Capillaries

- Extremely narrow (less than 1mm long)
- Microscopic tube+ one cell thick walls- endothelium with basement membrane
- Capillary beds- network of many capillaries present in all regions of body
- Cross sectional area- greater than that of arteries and veins
- Rate of blood flow (velocity)- lowest
- Exchange of substances takes place across their thin walls





In some parts of body,
Portal system- Associated with
Pituitary gland (Hypophyseal Portal System)
Liver (Hepatic Portal System)



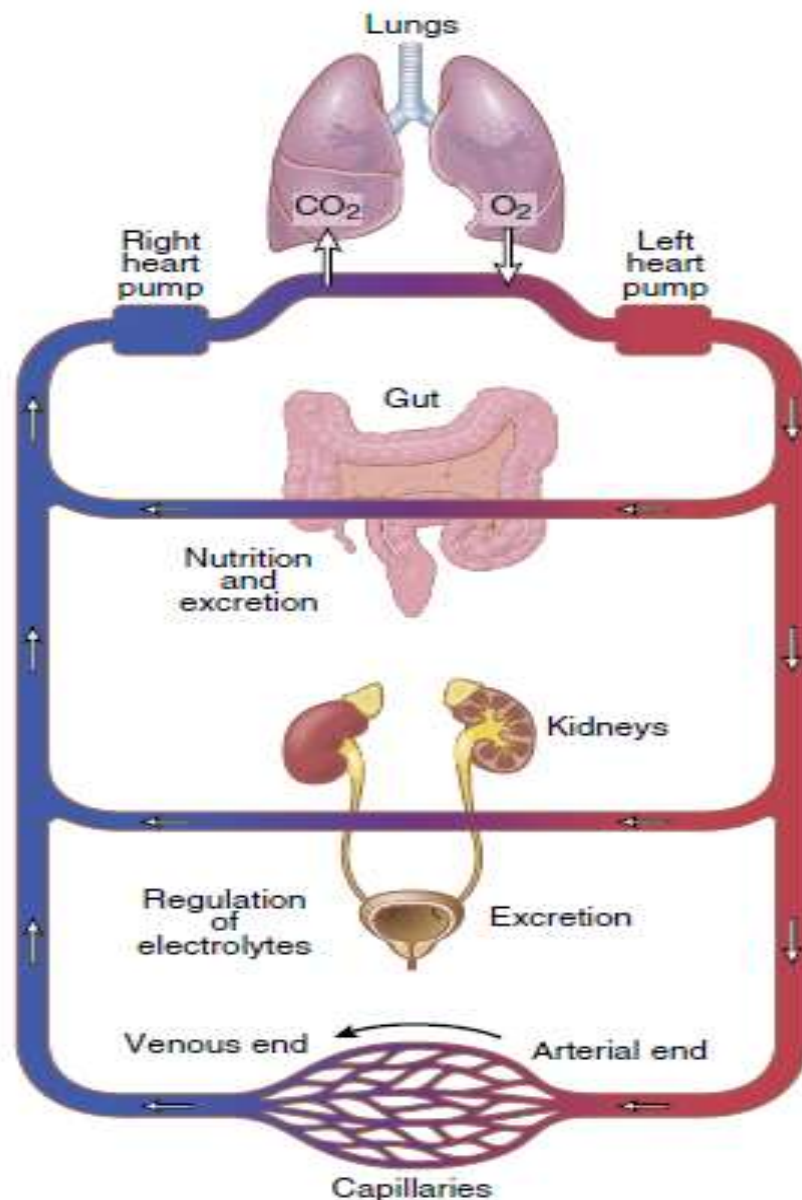


Figure 1-1. General organization of the circulatory system.

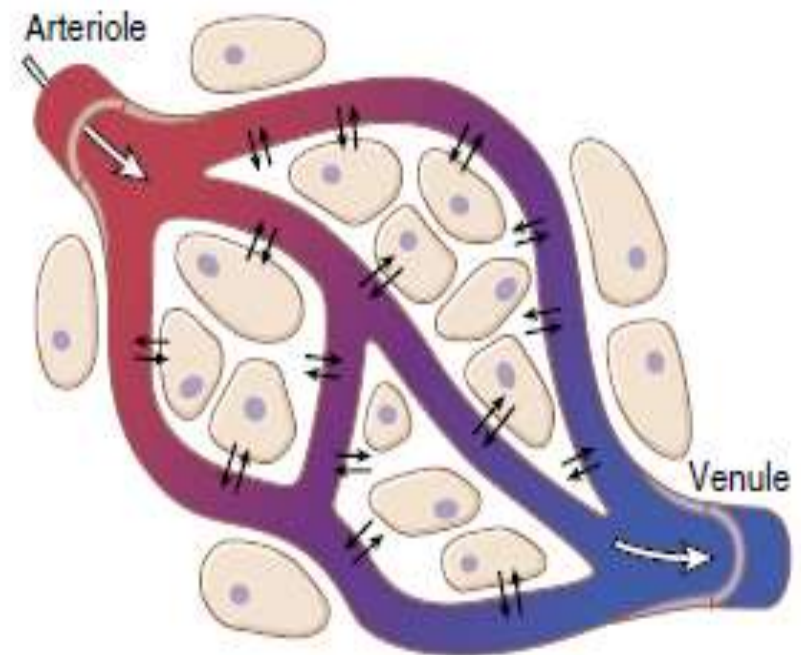


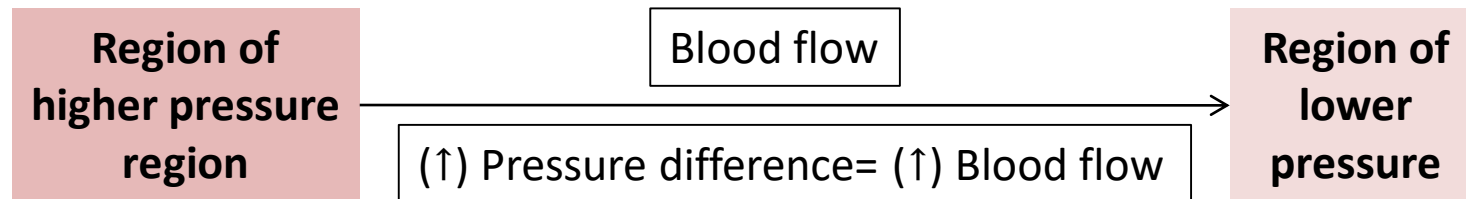
Figure 1-2. Diffusion of fluid and dissolved constituents through the capillary walls and interstitial spaces.

Source: John E Hall, Michael E Hall (2021),
Guyton and Hall Textbook of Medical
Physiology (14th Edition), Page no.5

Blood flow

- ≈ Quantity of blood that passes a given point in blood vessel in a given period of time
- ≈ Expressed in milliliters/ minute or liters/ minute
- ≈ 2 factors:
 - ≈ Pressure difference of blood between 2 ends of blood vessels
 - ≈ Vascular resistance

Factor:1 Pressure difference of blood between 2 ends of blood vessel



Factor:2 Vascular resistance

Blood flow has greater resistance

Smaller lumen

Higher blood viscosity

Longer blood vessels

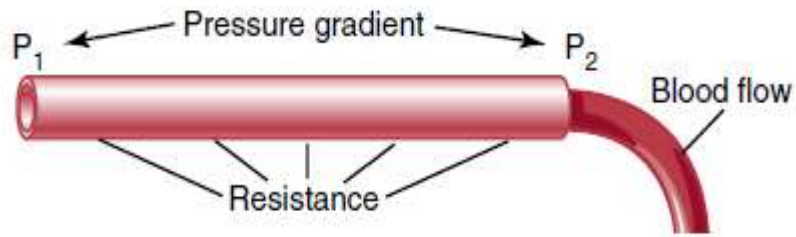


Figure 14-3. Interrelationships of pressure, resistance, and blood flow. P_1 , Pressure at the origin of the vessel; P_2 , pressure at the other end of the vessel.

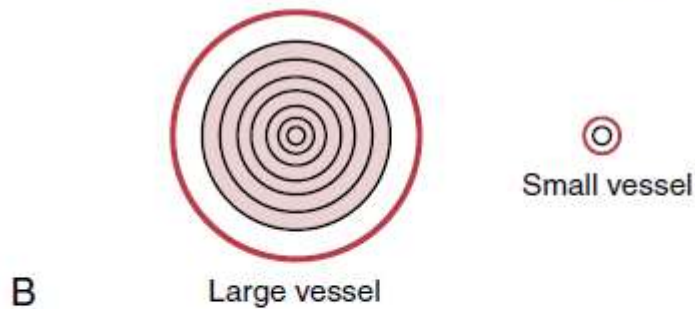
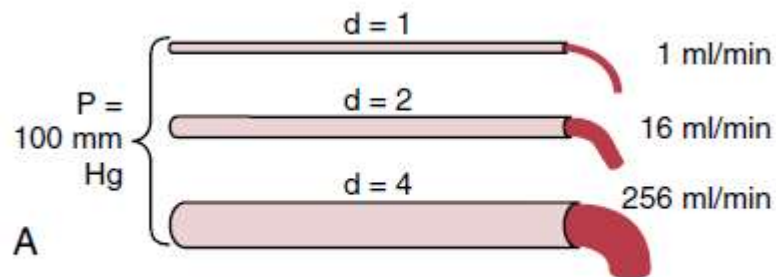


Figure 14-8. **A**, Demonstration of the effect of vessel diameter on blood flow. **B**, Concentric rings of blood flowing at different velocities; the farther away from the vessel wall, the faster the flow. d , diameter; P , pressure difference between the two ends of the vessels.

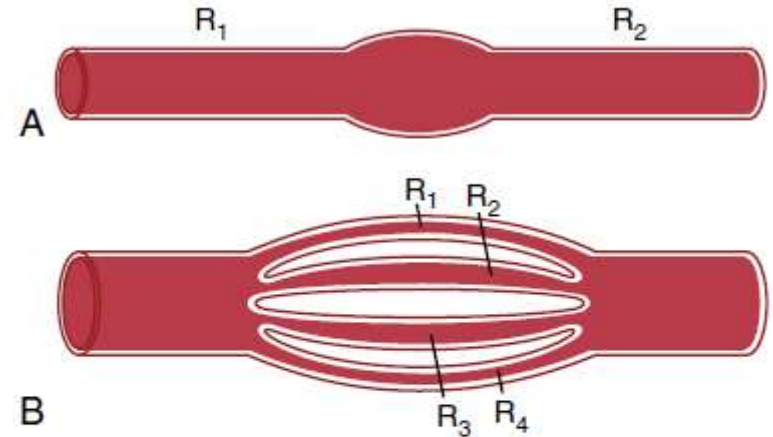


Figure 14-9. Vascular resistance (R). **A**, In series. **B**, In parallel.

$$\frac{1}{R_{\text{total}}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4} \dots$$

Source: John E Hall, Michael E Hall (2021),
Guyton and Hall Textbook of Medical
Physiology (14th Edition), Page no.173,
177, 178

Blood pressure

- Arterial pressure of blood exerted on walls of arteries with each heart beat

“Force exerted by blood against any unit area of wall of arteries”

- Measured in- millimeters of mercury- (**mmHg**)

Maximum pressure exerted in arteries when blood is ejected into them during systole

Systolic pressure
(120mmHg)

Lowest arterial pressure occurs while heart ventricles are relaxing

Diastolic pressure
(80mmHg)

Blood pressure= ratio of systolic pressure and diastolic pressure

Normal blood pressure= 120mmHg : 80 mmHg (120/80 mmHg)

Blood pressure taken in brachial artery of arm= 120/80 mmHg

Blood pressure varies throughout the body

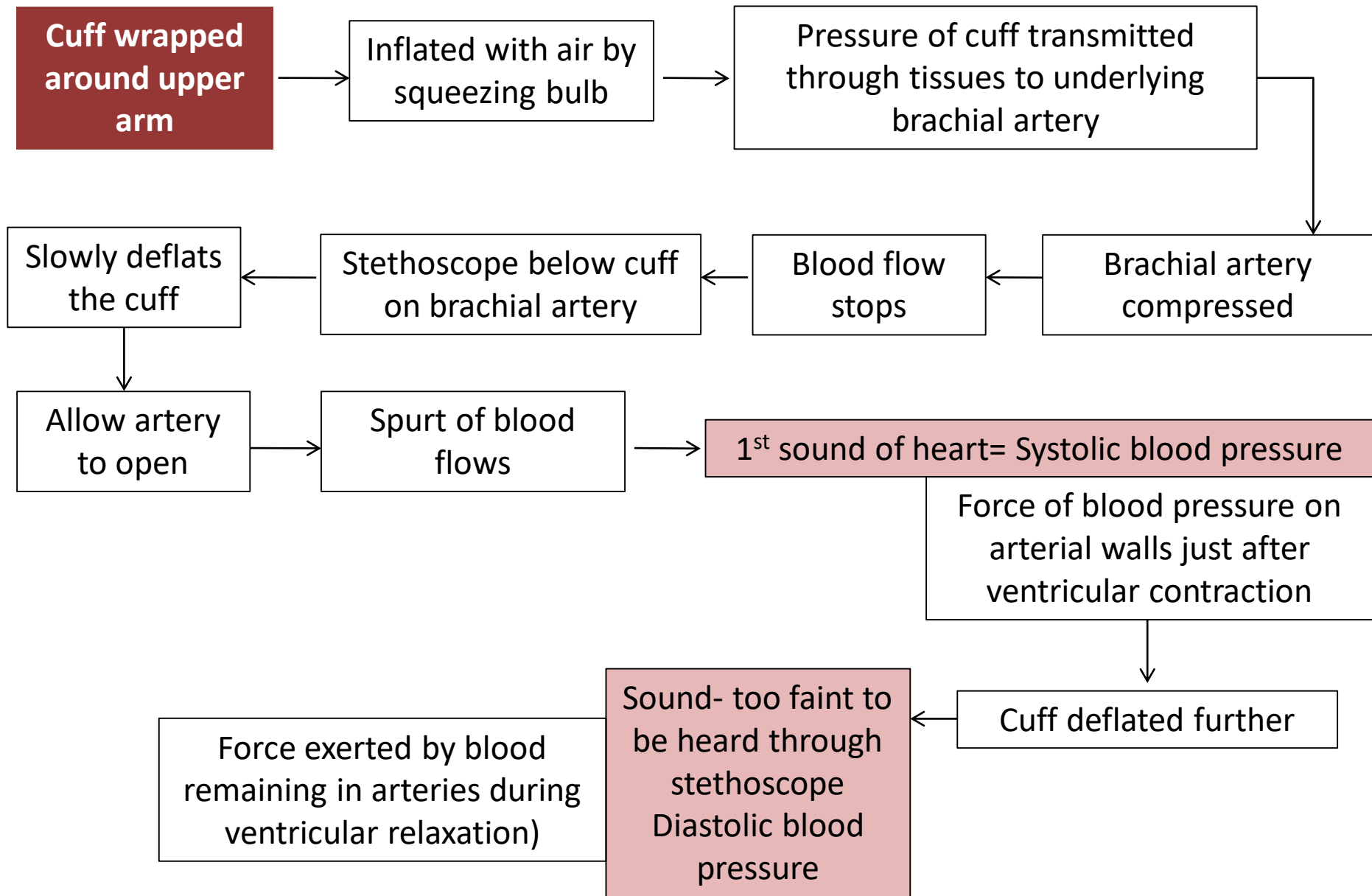
Highest= Aorta

Lowest= Venae Cavae

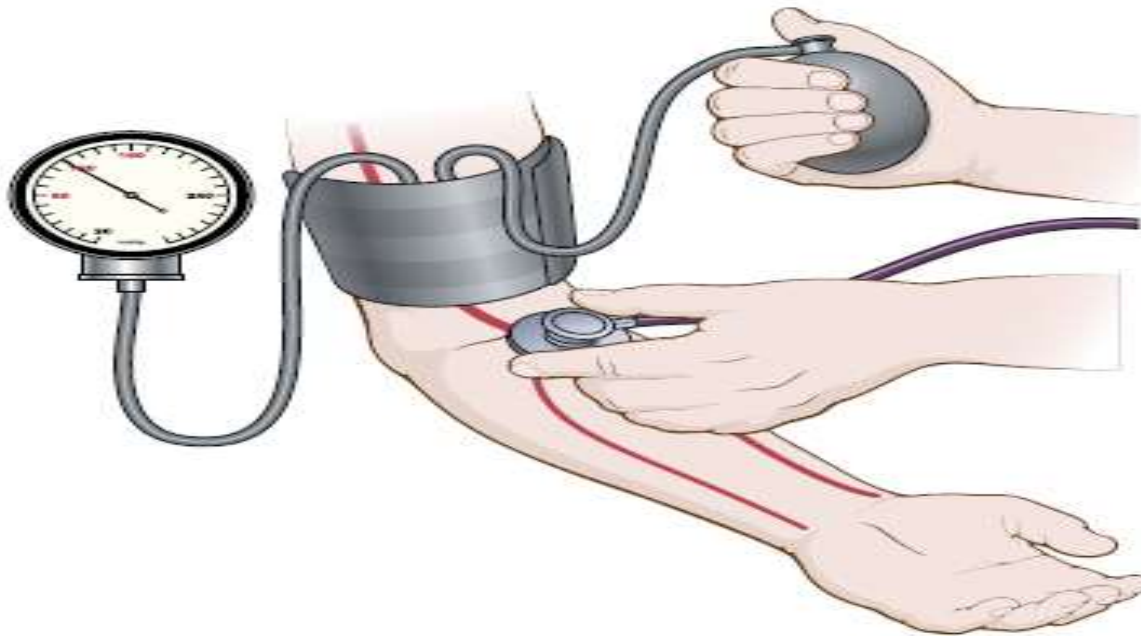
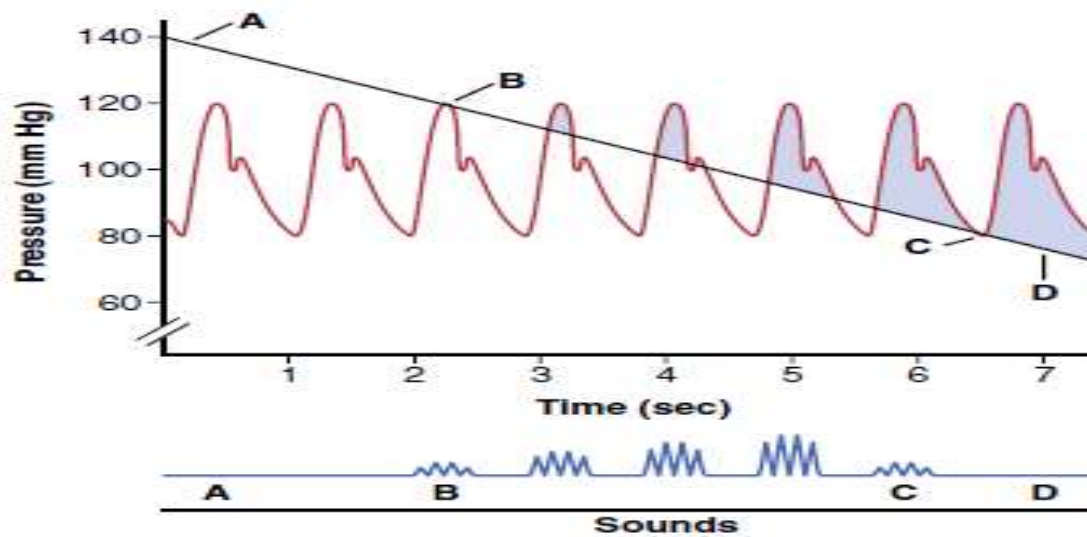
Difference of systolic and diastolic blood pressure= pulse pressure

Measuring blood pressure: Sphygmomanometer

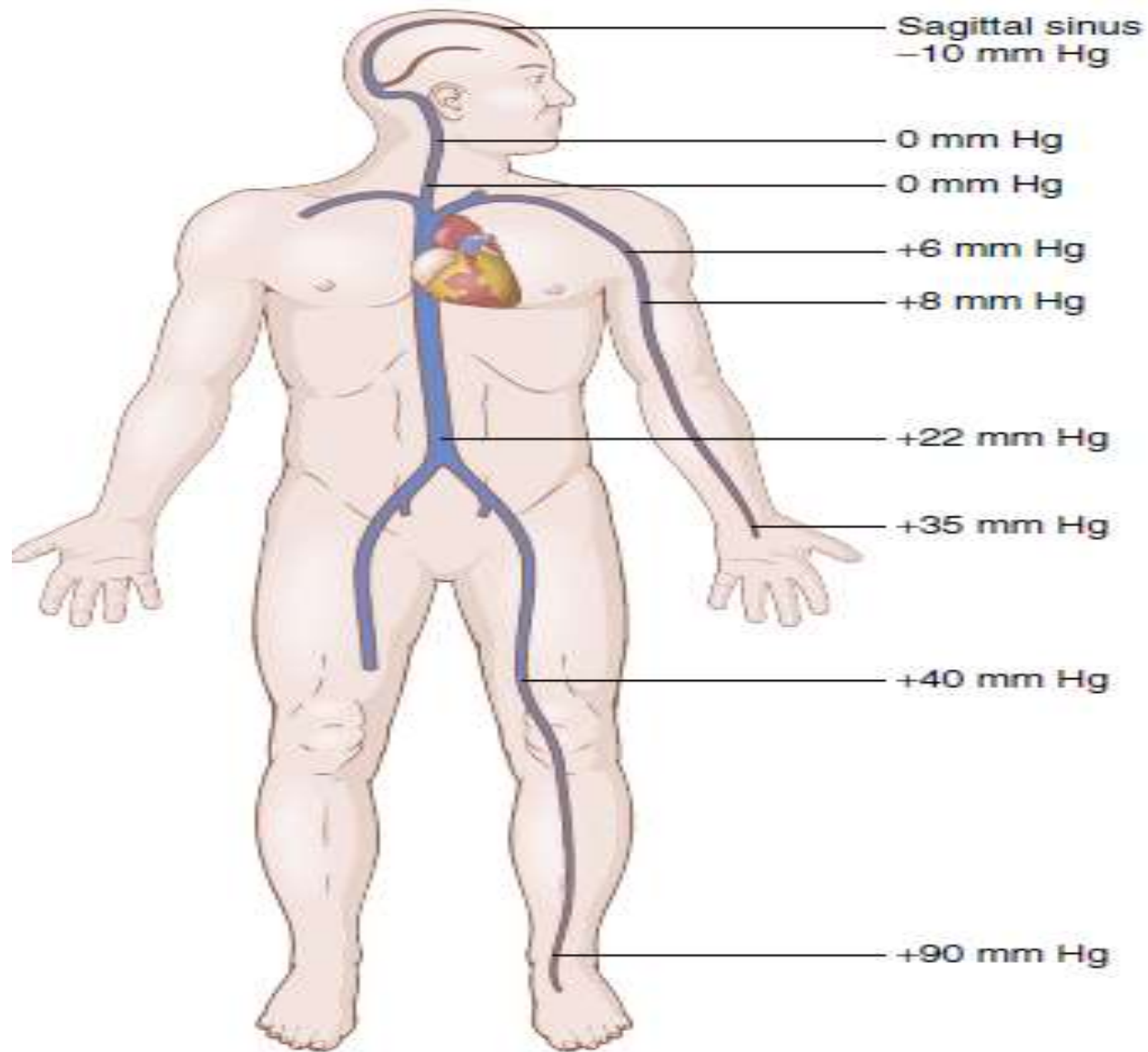
Externally applied inflatable cuff attached to pressure gauge



Measuring blood pressure



Source: John E Hall, Michael E Hall (2021), Guyton and Hall Textbook of Medical Physiology (14th Edition), Page no.187



Source: John E Hall, Michael E Hall (2021), Guyton and Hall Textbook of Medical Physiology (14th Edition), Page no.189

High blood pressure

Blood pressure in arteries (↑)

Primary hypertension

90% cases

High blood pressure that cannot be attributed to any identifiable cause

Genetic tendency

Hastened by factors:

Obesity

Stress

Smoke

Dietary habits

Secondary hypertension

10% Cases

High blood pressure due to identifiable causes like,

-**Obstruction of renal blood flow/** disorders that damage renal tissue cause kidney to release excessive rennin into blood
(↑) Angiotensin II= Vasoconstriction= (↑) systemic vascular resistance

- Hyper secretion of aldosterone

Stimulates excess reabsorption of salt and water by kidney

(↑) volume of blood fluids

-Hyper secretion of epinephrine/ Nor epinephrine

(↑) Heart rate and contractility

Control of blood pressure

Neural regulation

Cardiovascular center- In Medulla oblongata

Sensory receptors
gives input to

Cardiovascular
center sends
output through

Regulated Blood
pressure via
negative
feedback reflex
mechanism

Sympathetic and
parasympathetic
divisions of ANS

Baroreceptor
reflexes

Chemoreceptor
reflexes

Hormonal regulation

Angiotensin II

Epinephrine and nor
epinephrine

Vasopressin/
Antidiuretic hormone

Atrial natriuretic
peptide

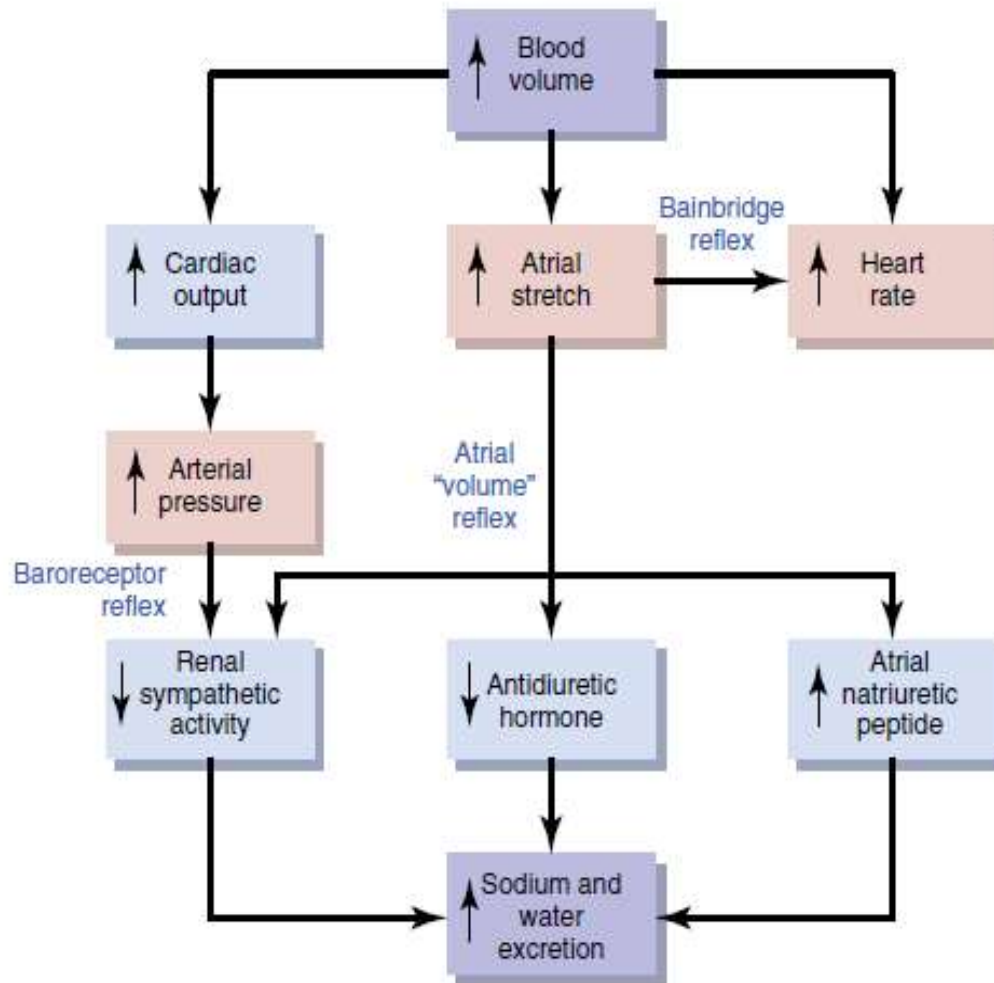
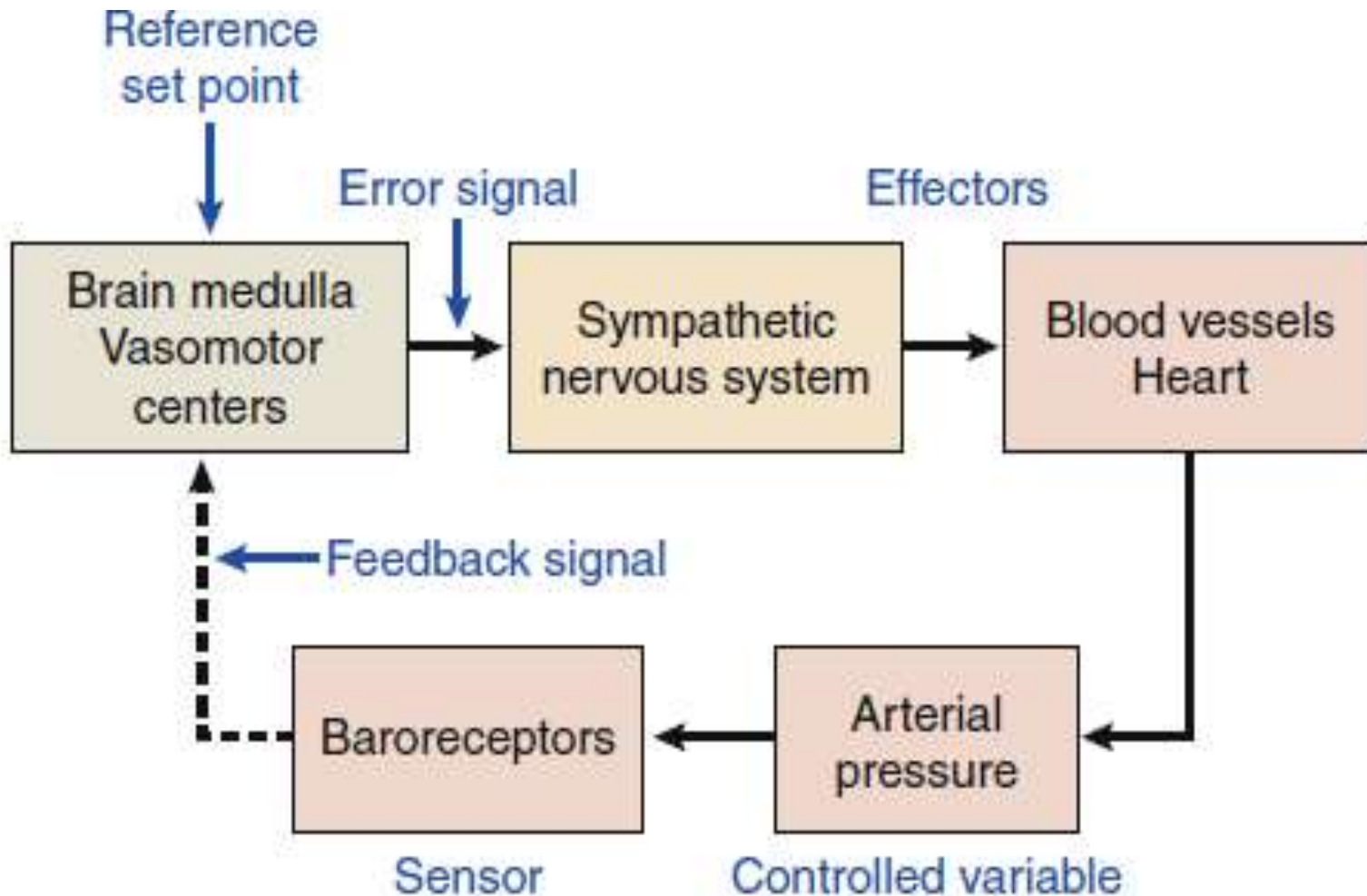


Figure 18-10. Reflex responses to increased blood volume which increase arterial pressure and atrial stretch.

Source: John E Hall, Michael E Hall (2021), Guyton and Hall Textbook of Medical Physiology (14th Edition), Page no.225

Negative feedback mechanisms



Source: John E Hall, Michael E Hall (2021), Guyton and Hall Textbook of Medical Physiology (14th Edition), Page no.7

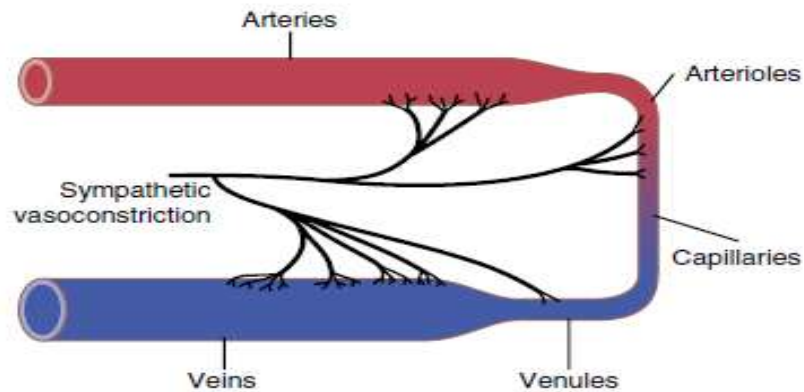


Figure 18-2. Sympathetic innervation of the systemic circulation.

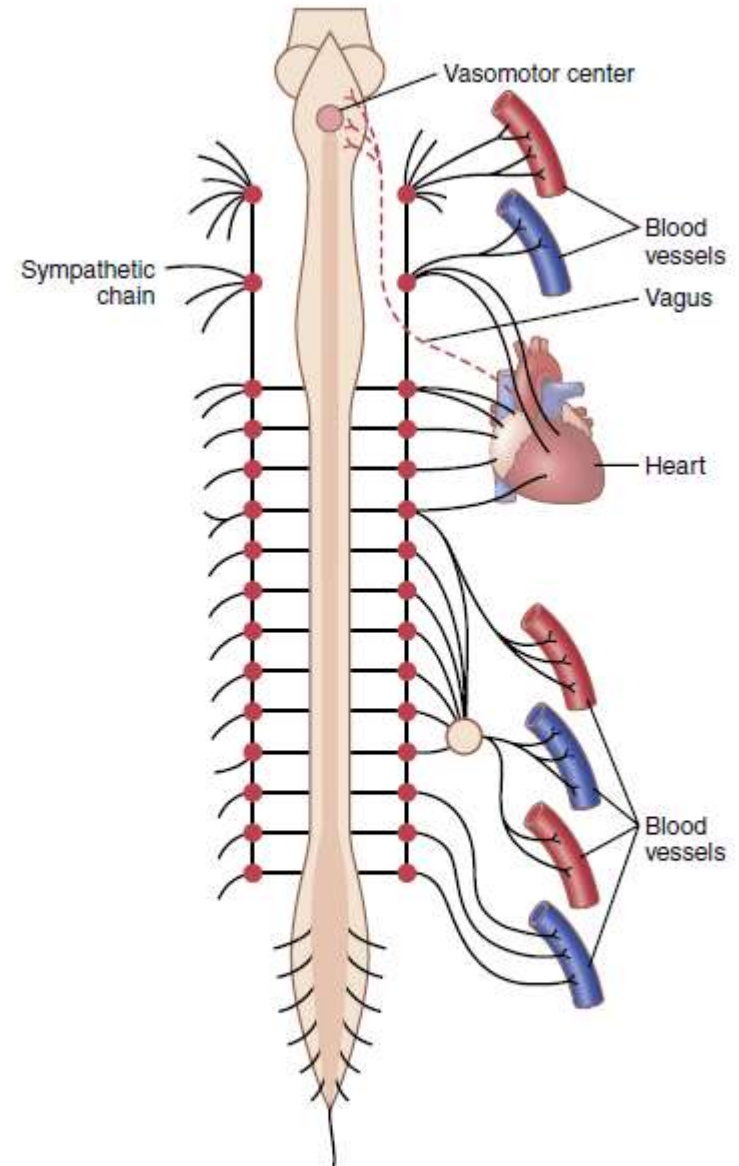


Figure 18-1. Anatomy of sympathetic nervous control of the circulation. Also, shown by the dashed red line, is a vagus nerve that carries parasympathetic signals to the heart.

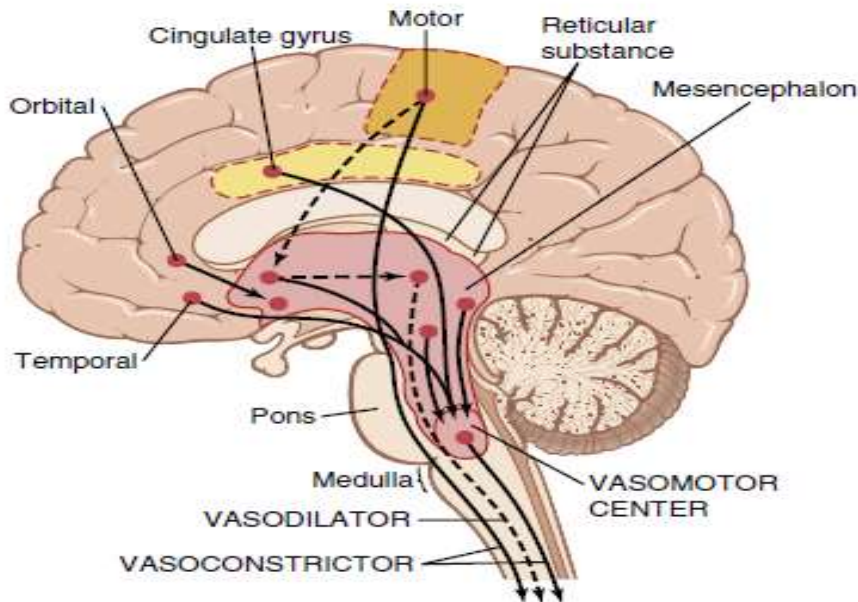


Figure 18-3. Areas of the brain that play important roles in the nervous regulation of the circulation. The dashed lines represent inhibitory pathways.

Source: John E Hall, Michael E Hall (2021),
Guyton and Hall Textbook of Medical
Physiology (14th Edition), Page no.218

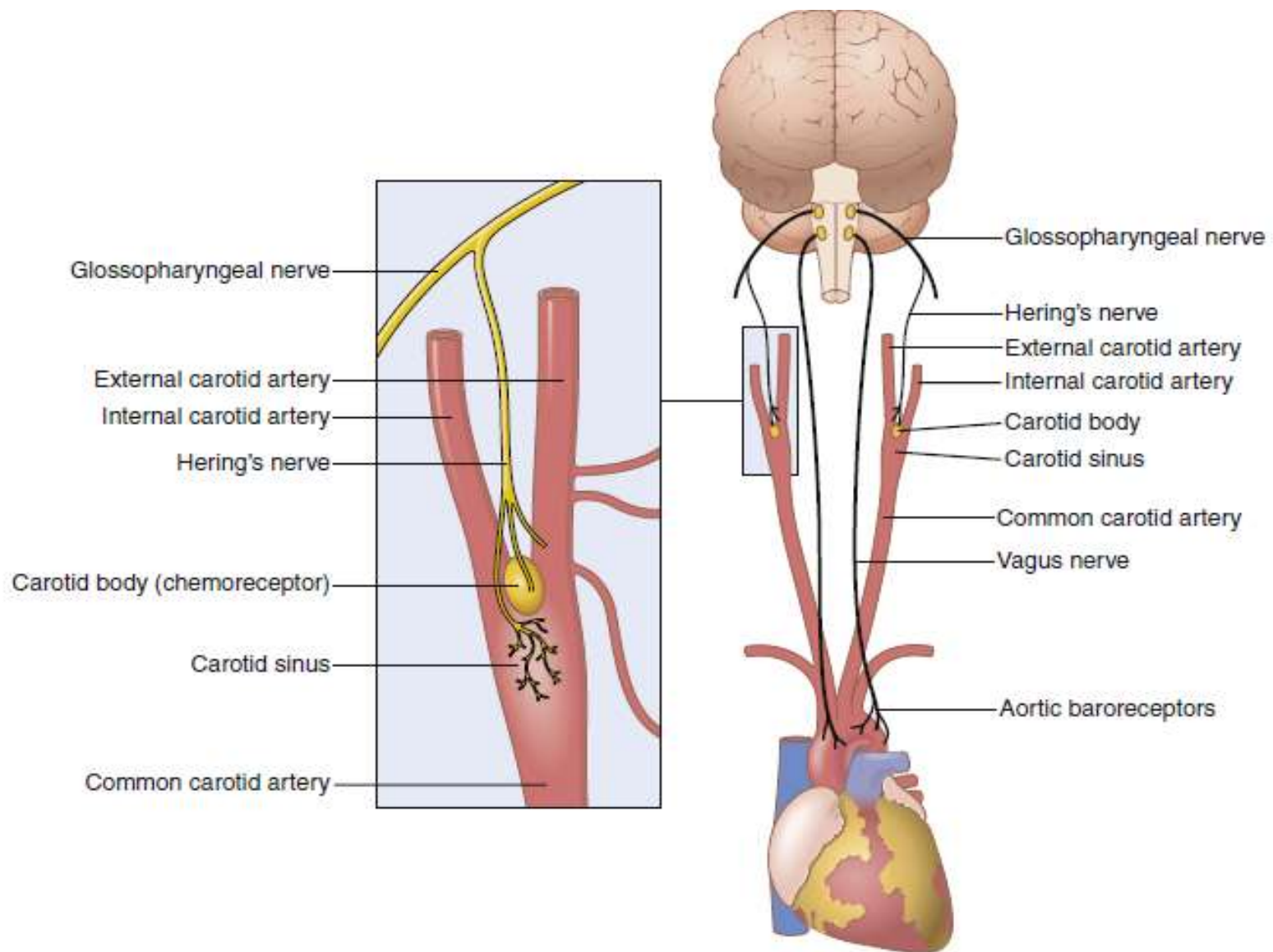
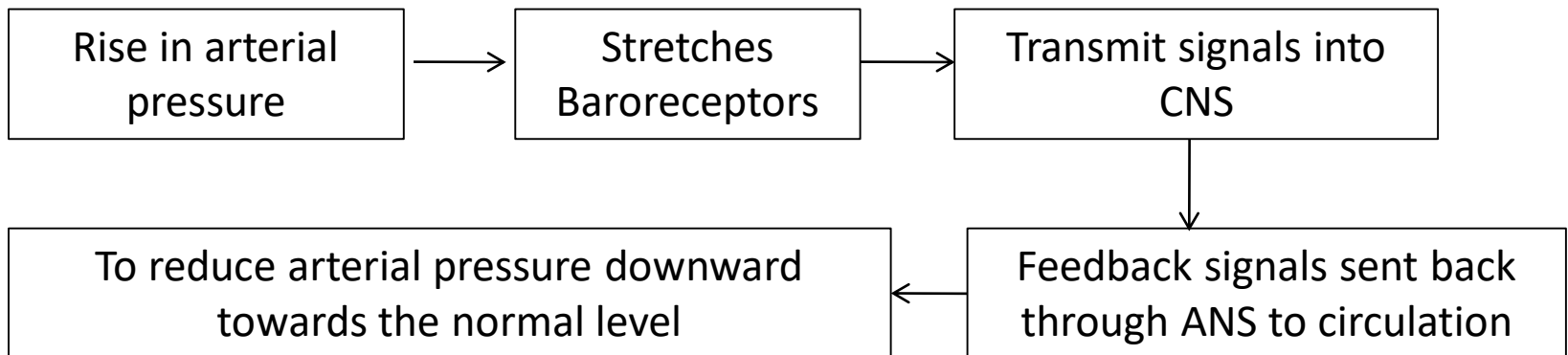


Figure 18-5. Baroreceptor system for controlling arterial pressure.

Source: John E Hall, Michael E Hall (2021), Guyton and Hall Textbook of Medical Physiology (14th Edition), Page no.221

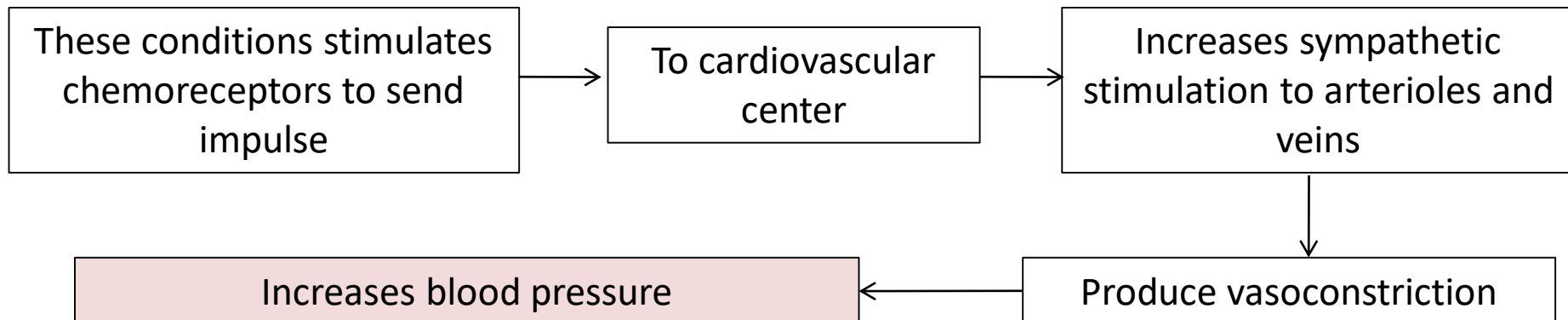
Baroreceptor reflexes

- Accomplished by negative feedback systems
- Pressure sensor (Baroreceptors/ pressoreceptors) = senses the arterial pressure
- Baroreceptors- pressure- sensitive neurons- monitor stretching



Chemoreceptor reflexes

- Sensory receptors
- Monitor chemical composition of blood
- Located close to Baroreceptors of carotid sinus and aortic arch in small structures called carotid body and aortic body
- Chemoreceptors- detects changes in blood level of oxygen, carbon dioxide, hydrogen ions
- Hypoxia- low oxygen level
- Acidosis- high hydrogen ion concentration
- Hypercapnia- high carbon dioxide



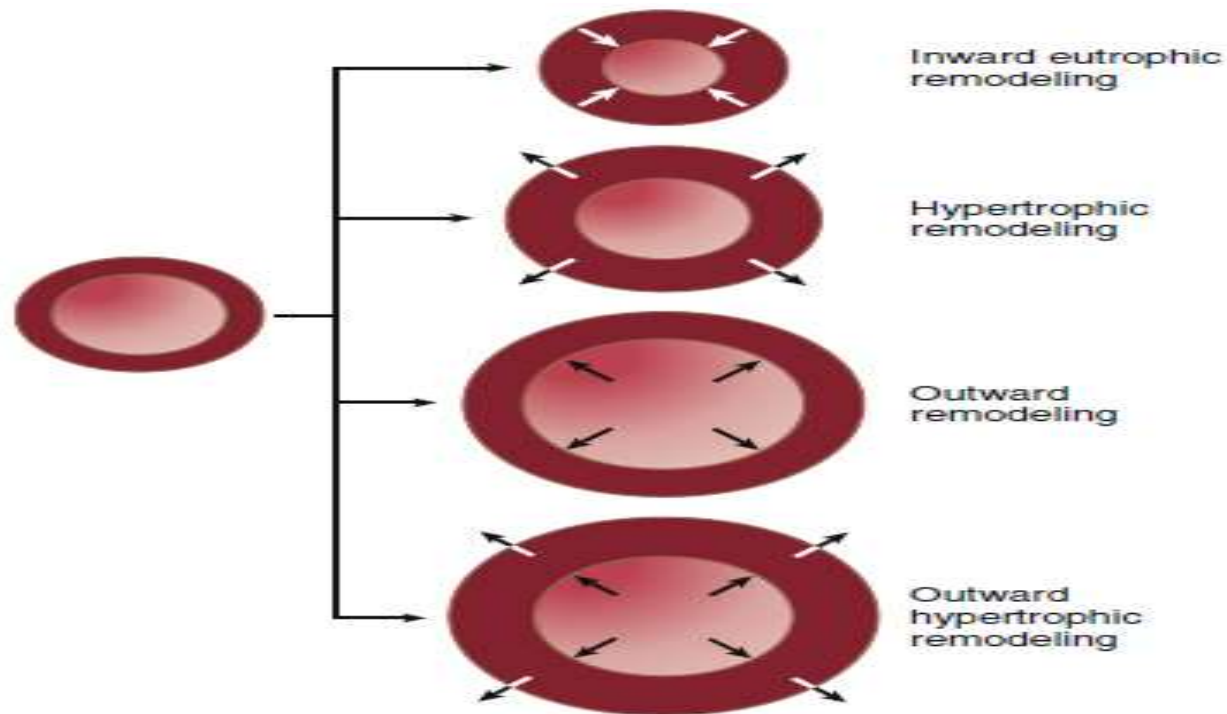


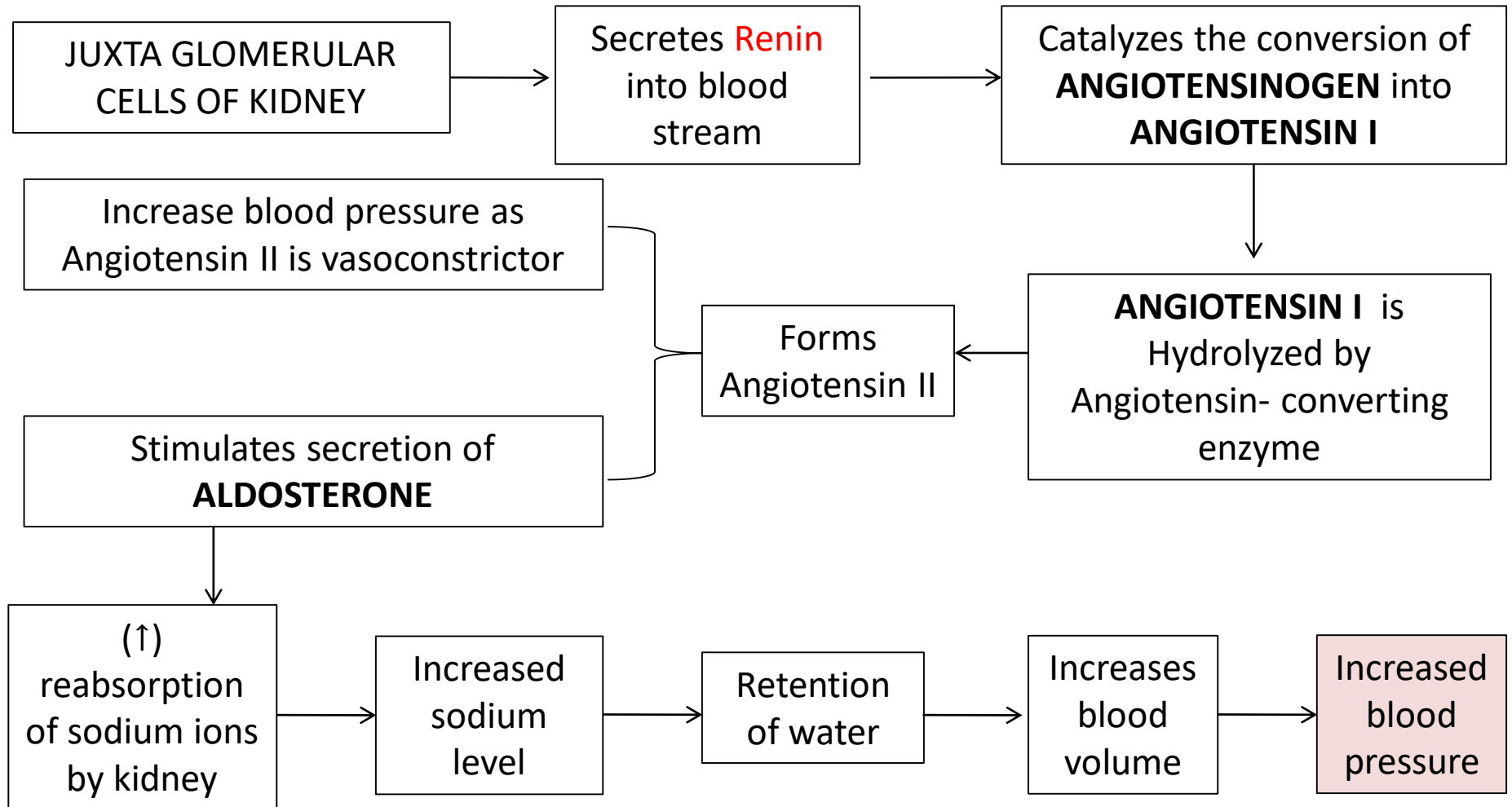
Figure 17-8. Vascular remodeling in response to a chronic increase in blood pressure or blood flow. In small arteries and arterioles that constrict in response to increased blood pressure, *inward eutrophic remodeling* typically occurs because the lumen diameter is smaller and the vascular wall is thicker, but the total cross-sectional area of the vessel wall is hardly changed. In large blood vessels that do not constrict in response to increased blood pressure, there may be *hypertrophic remodeling*, with increases in thickness and total cross-sectional area of the vascular wall. If blood vessels are exposed to chronic increases in blood flow, there is typically *outward remodeling*, with increases in lumen diameter, little change in wall thickness, and increased total cross-sectional area of the vascular wall. If the blood vessel is exposed to long-term increases in blood pressure and blood flow, there is usually *outward hypertrophic remodeling*, with increases in lumen diameter, wall thickness, and total cross-sectional area of the vascular wall. Chronic reductions in blood pressure and blood flow have the opposite effects, as previously described.

Source: John E Hall, Michael E Hall (2021), Guyton and Hall Textbook of Medical Physiology (14th Edition), Page no.213

Hormonal regulation

1. Angiotensin II

- Powerful vasoconstrictor
- Blood volume falls/ blood flow to kidney (↓)



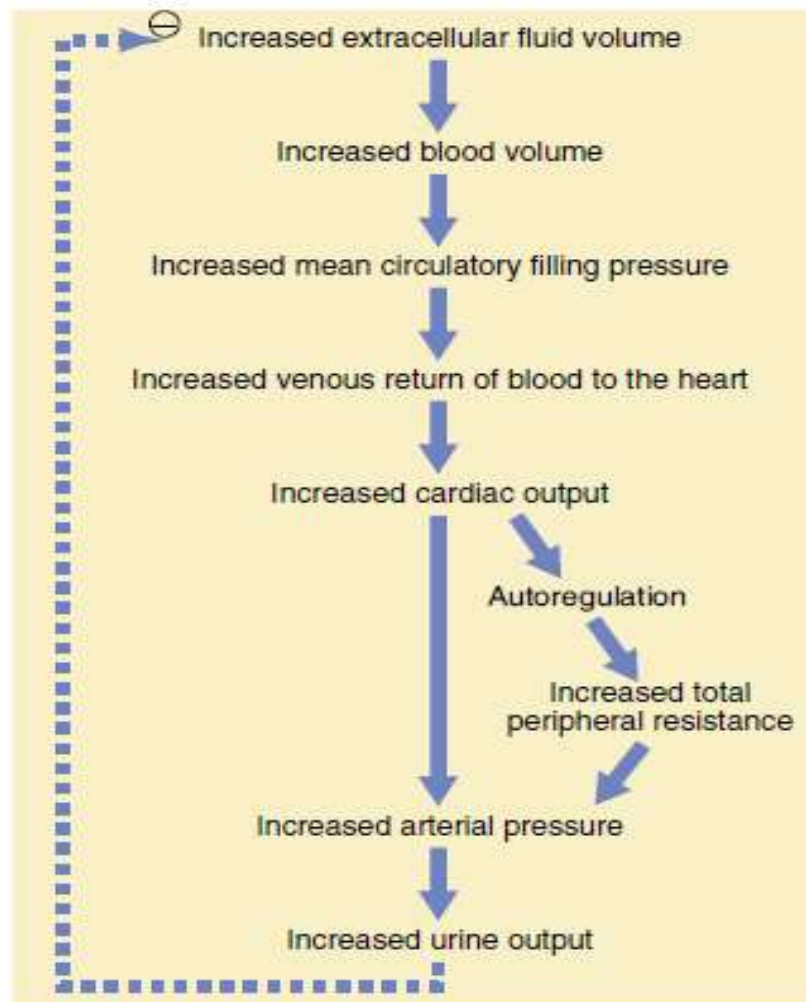


Figure 19-6. Sequential steps whereby increased extracellular fluid volume increases the arterial pressure. Note especially that increased cardiac output has both a *direct effect* to increase arterial pressure and an *indirect effect* by first increasing the total peripheral resistance.

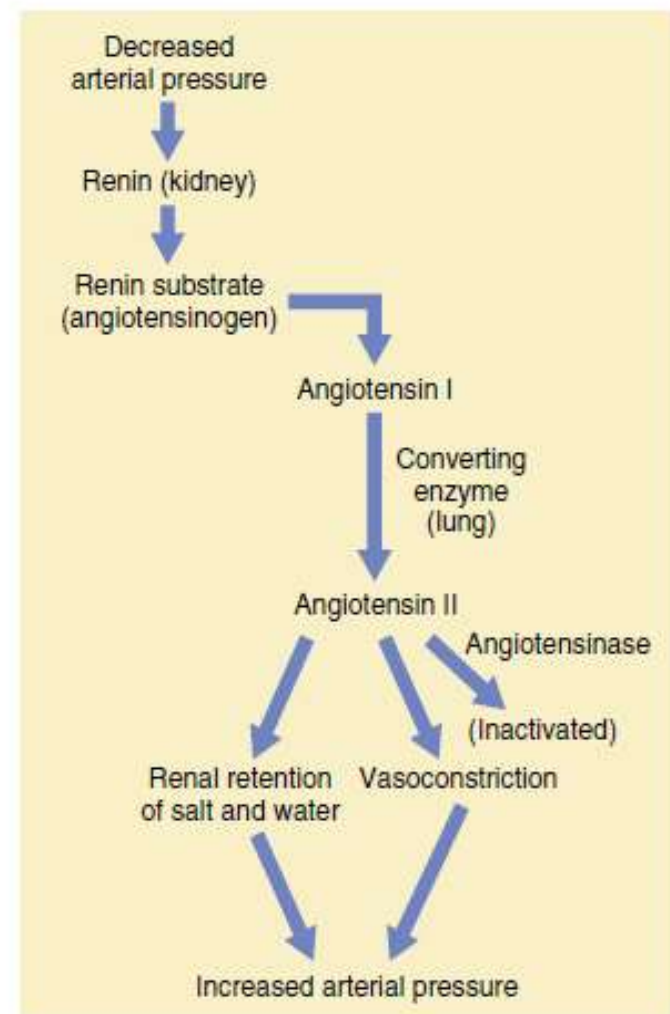


Figure 19-9. The renin-angiotensin vasoconstrictor mechanism for arterial pressure control.

Source: John E Hall, Michael E Hall (2021), Guyton and Hall Textbook of Medical Physiology (14th Edition), Page no.233, 236

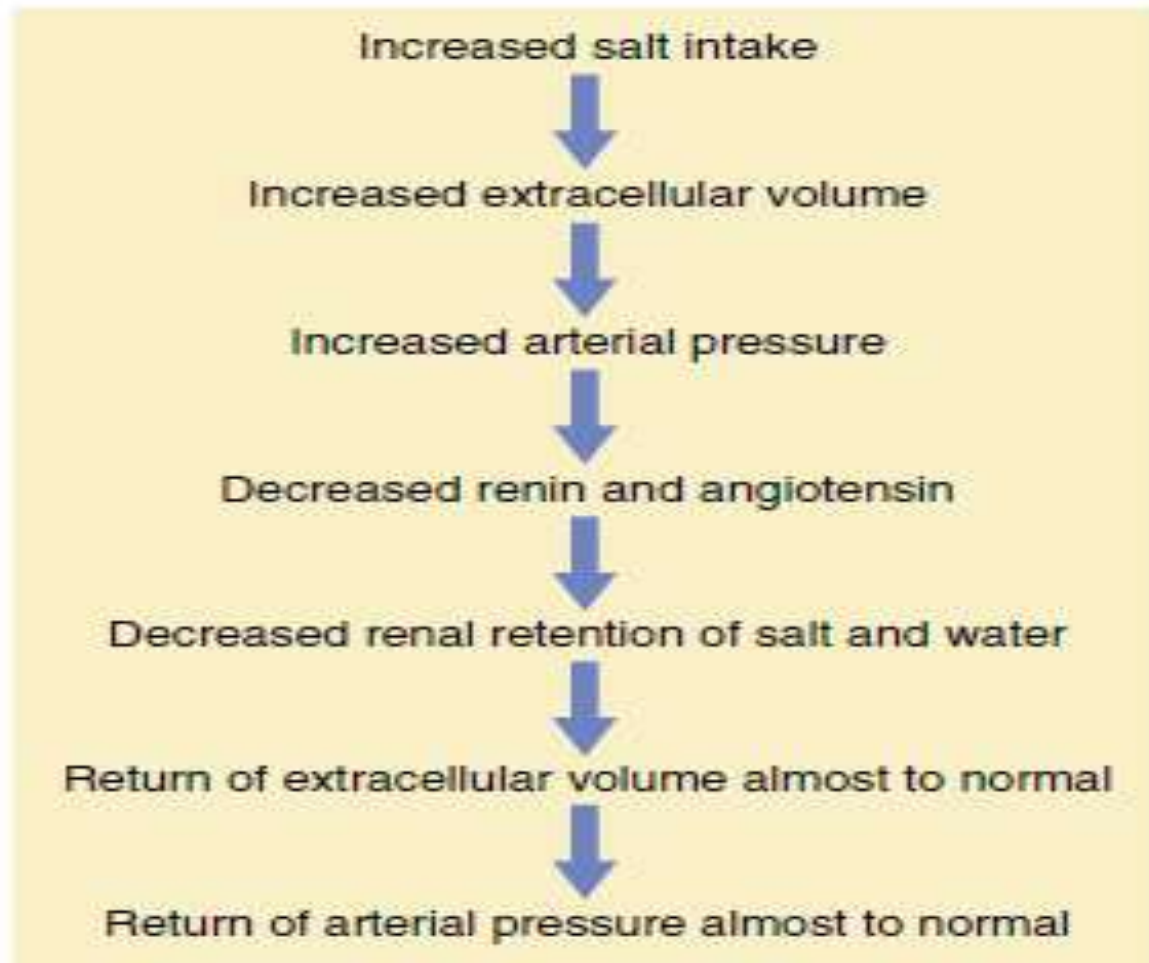
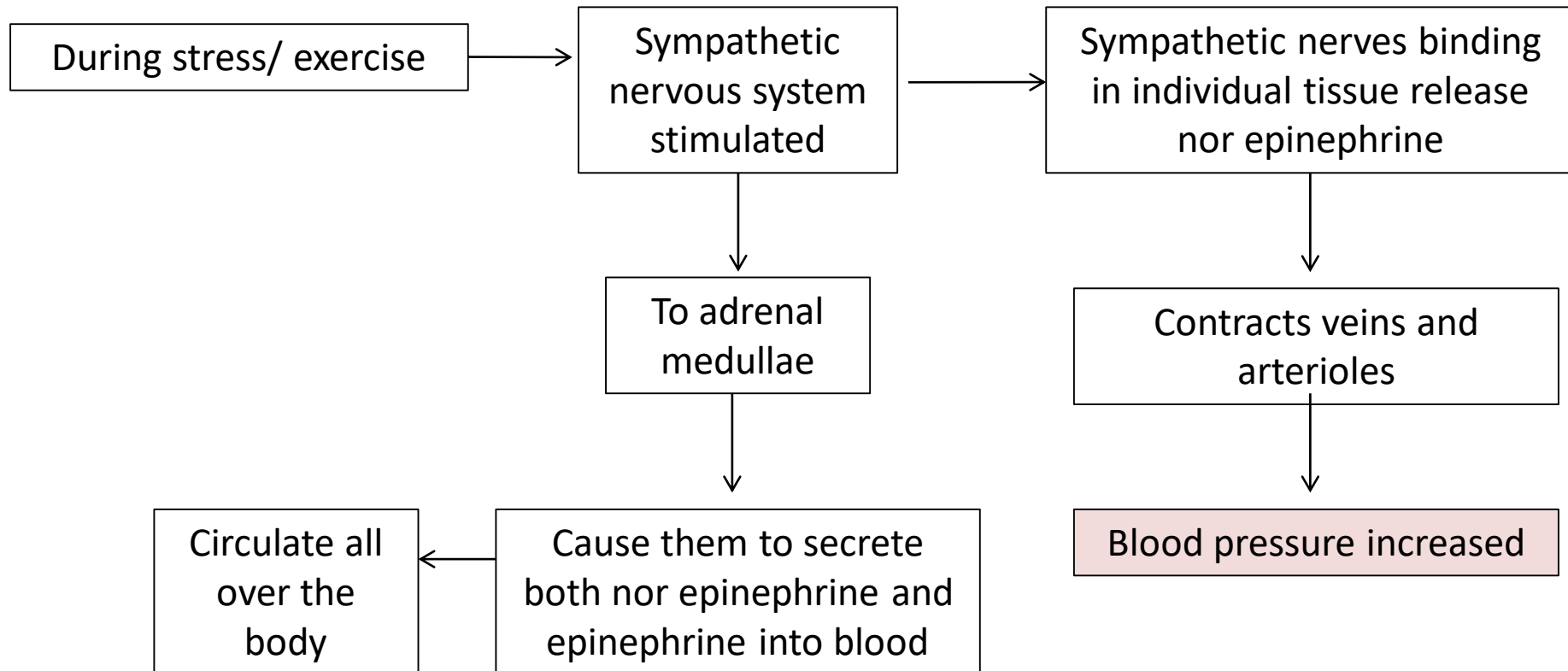


Figure 19-12. Sequential events whereby increased salt intake increases the arterial pressure, but feedback decrease in activity of the renin angiotensin system returns the arterial pressure almost to the normal level.

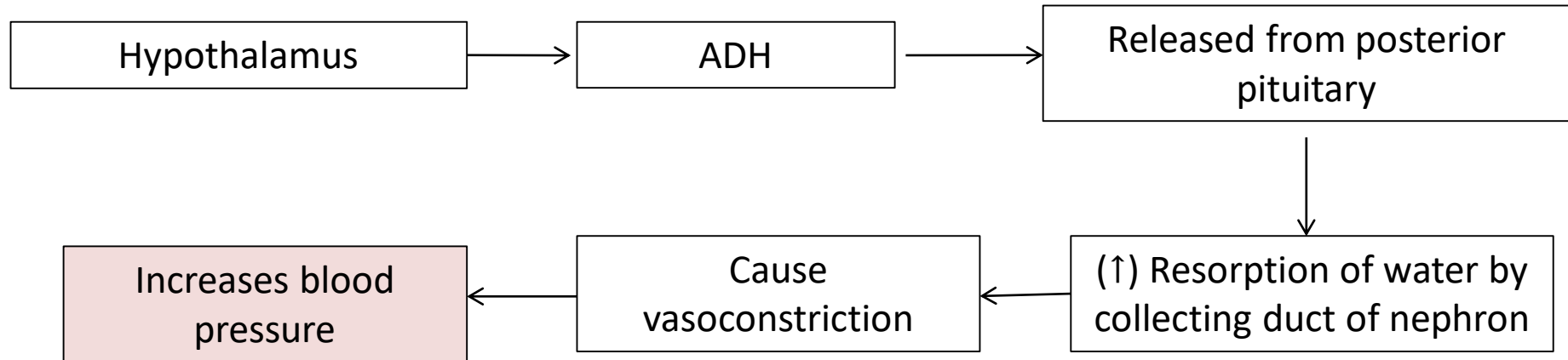
Source: John E Hall, Michael E Hall (2021), Guyton and Hall Textbook of Medical Physiology (14th Edition), Page no.238

2. Epinephrine and nor epinephrine

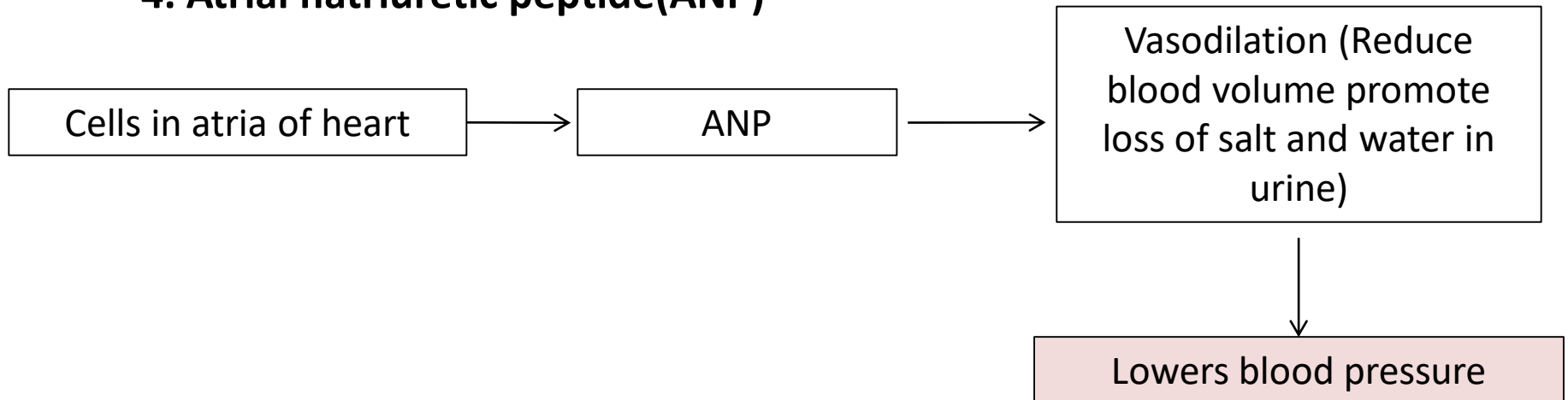
- Nor epinephrine- vasoconstrictor hormone (powerful)
- Epinephrine- vasoconstrictor hormone (mild)



3. Vasopressin/ Antidiuretic hormone (ADH)



4. Atrial natriuretic peptide(ANP)



Circulatory routes

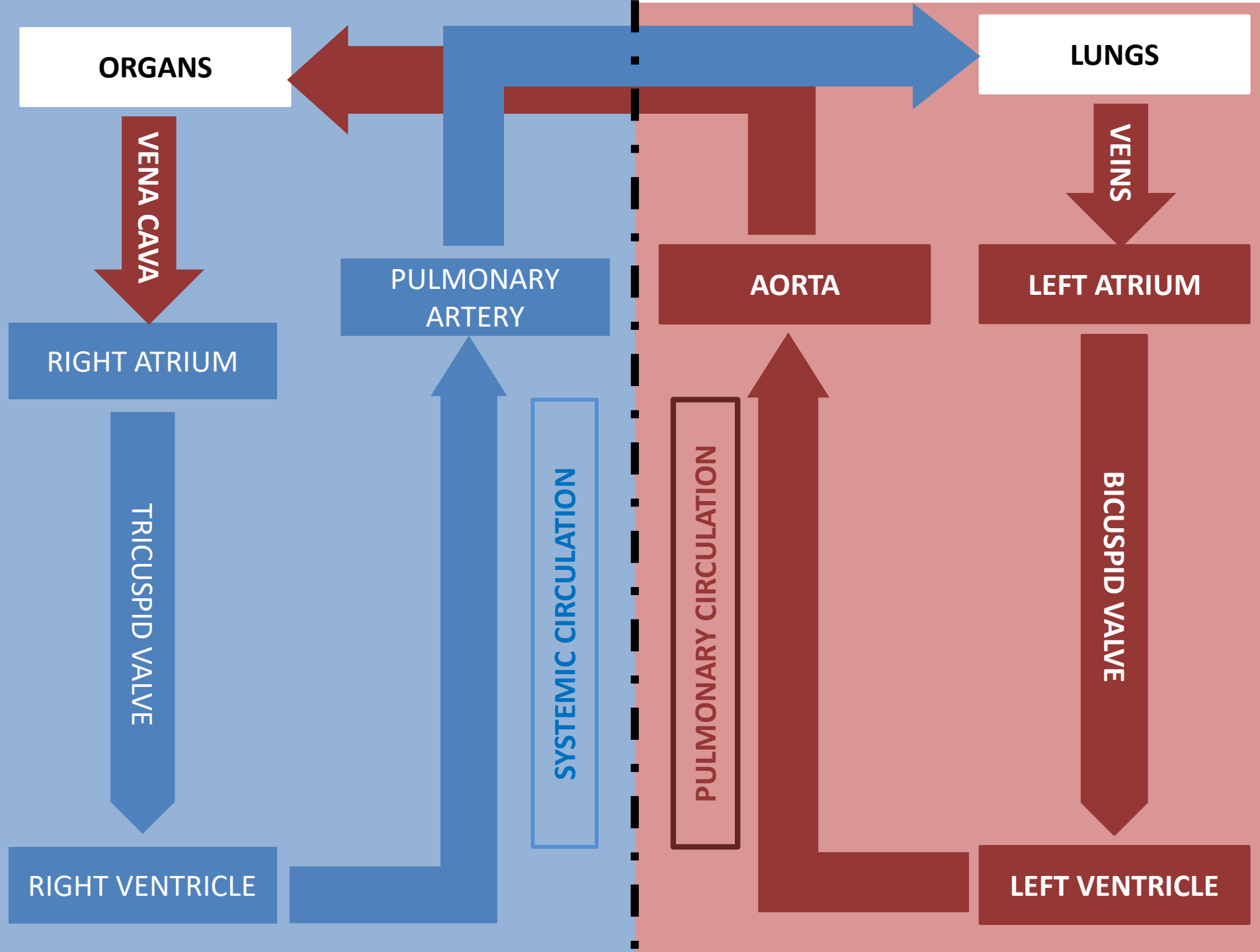
2 Main circulatory routes

Systemic circulations

- This circulation supplies blood flow to all tissues of body except lungs
- Also called **Greater circulation/ Peripheral circulation**
- **Arteries and arterioles**- Carry oxygenated blood from left ventricle to systemic capillaries
- **Veins and Venules**- Return deoxygenated blood to right atrium
- **SUBDIVISIONS:**
 - **Coronary (cardiac) circulation**
 - **Hepatic portal circulation**

Pulmonary circulations

- This circulation carries deoxygenated blood from right ventricle to air sacs (alveoli) within lungs and return oxygenated blood from air sacs to left atrium
- **Pulmonary trunk**- emerges from right ventricles
- Divides into 2 branches:
 - **Right pulmonary artery** to right lung
 - **Left pulmonary artery** to left lung



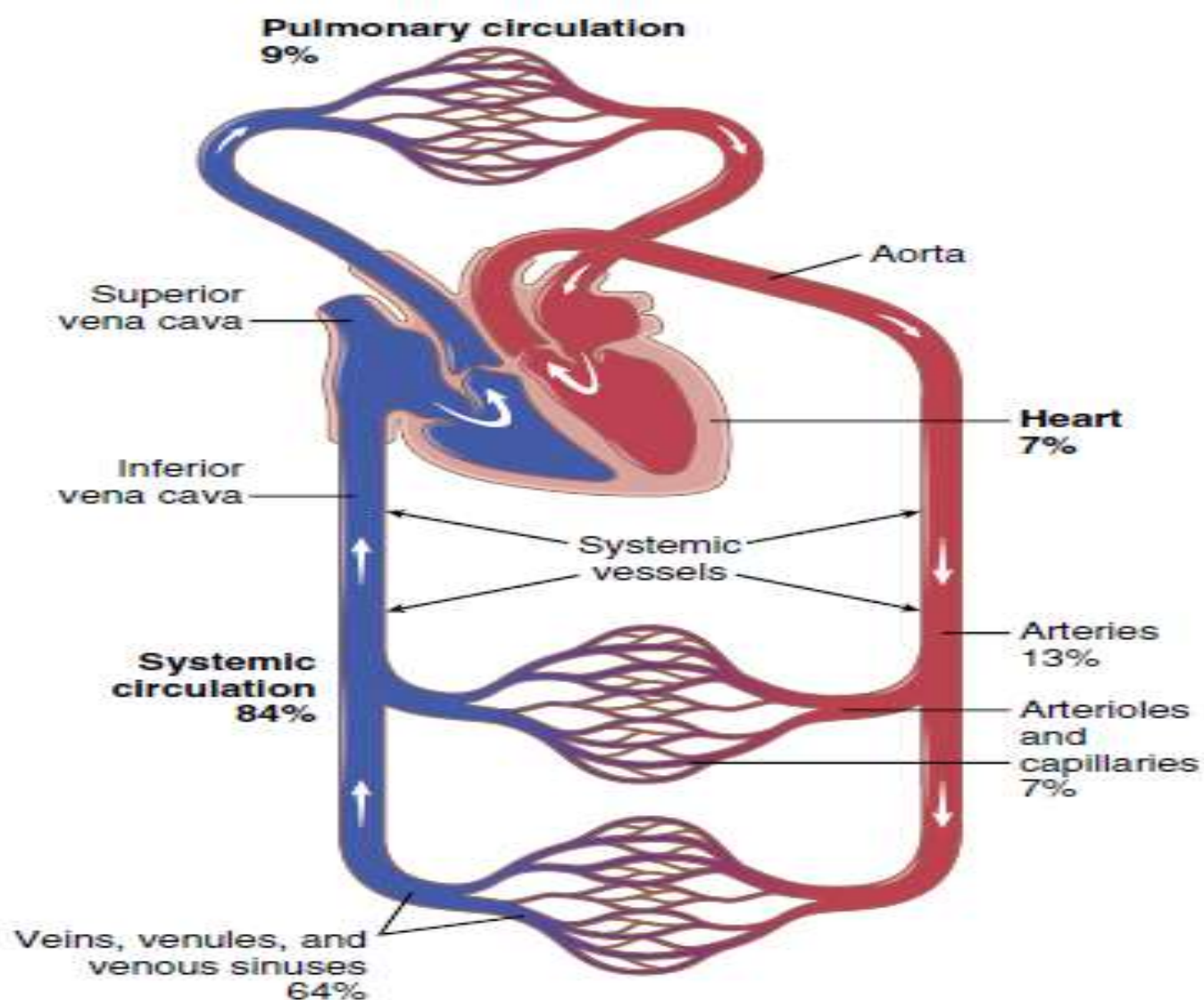


Figure 14-1. Distribution of blood (in percentage of total blood) in the different parts of the circulatory system.

Source: John E Hall, Michael E Hall (2021), Guyton and Hall Textbook of Medical Physiology (14th Edition), Page no.171

Cardiovascular disorders

- Disease of heart/ blood vessels
- 4 main types of cardiovascular diseases:
 - Coronary heart disease
 - Stroke
 - Peripheral arterial disease
 - Aortic disease

1. Coronary artery disease (Coronary heart disease)

- Cause narrowing of coronary arteries
- Blood flow to heart reduced
- Atherosclerosis:
 - affects coronary arteries that supply blood to heart muscle
 - Progressive degenerative arterial disease
 - Results from accumulation of **atherosclerotic plaques** in coronary arteries
 - Reduction in blood flow to myocardium
 - Atherosclerotic plaque:
 - lipid rich core
 - covered by an abnormal overgrowth of smooth muscle cells
 - made up of fat, cholesterol, calcium, and other substances found in blood

2. Heart failure

- Occurs when heart can't pump enough blood to meet body's needs
- Heart cannot pump enough oxygen and nutrients to meet body's needs
- Heart's pumping power is weaker than normal
- Not same as cardiac arrest (Heart stops beating)/ heart attack (Heart muscle suddenly damaged by an inadequate supply)
- Caused by the condition that damage heart muscle
- Called congestive heart failure- congestion of lungs

References:

1. John E Hall, Michael E Hall (2021), Guyton and Hall, Textbook of Medical Physiology (14th Edition), Page no.171
2. Pranav Kumar, Usha Mina (2018), Life Science Fundamentals and practice II, Pathfinder publication, 6th edition, Page no. 491-506